

TRUCKEE BYPASS TEST PLOTS SITE REPORT

May 2008

INTRODUCTION

This report describes monitoring data and results from Truckee Bypass test plots, the Caltrans Erosion Control Type D (EC Type D) irrigated plot, and a native reference site. Monitoring took place in both 2006 and 2007. The test plots were built in 2005 and are located on the corner of Brockway Road and Highway 267 in Truckee, California (Figure 1 and Figure 2). Further north on Highway 267 is the Caltrans irrigated EC Type D slope re-vegetation, which was also included in the 2006 and 2007 monitoring (Figure 2). The native reference sampling area is also located north of the test plots on a side street, and was monitored in 2007, the year it was established (Figure 2). These cut slopes are representative of Caltrans roadside project in the Lake Tahoe area, therefore, the monitoring results from this project will be applicable Basin-wide.

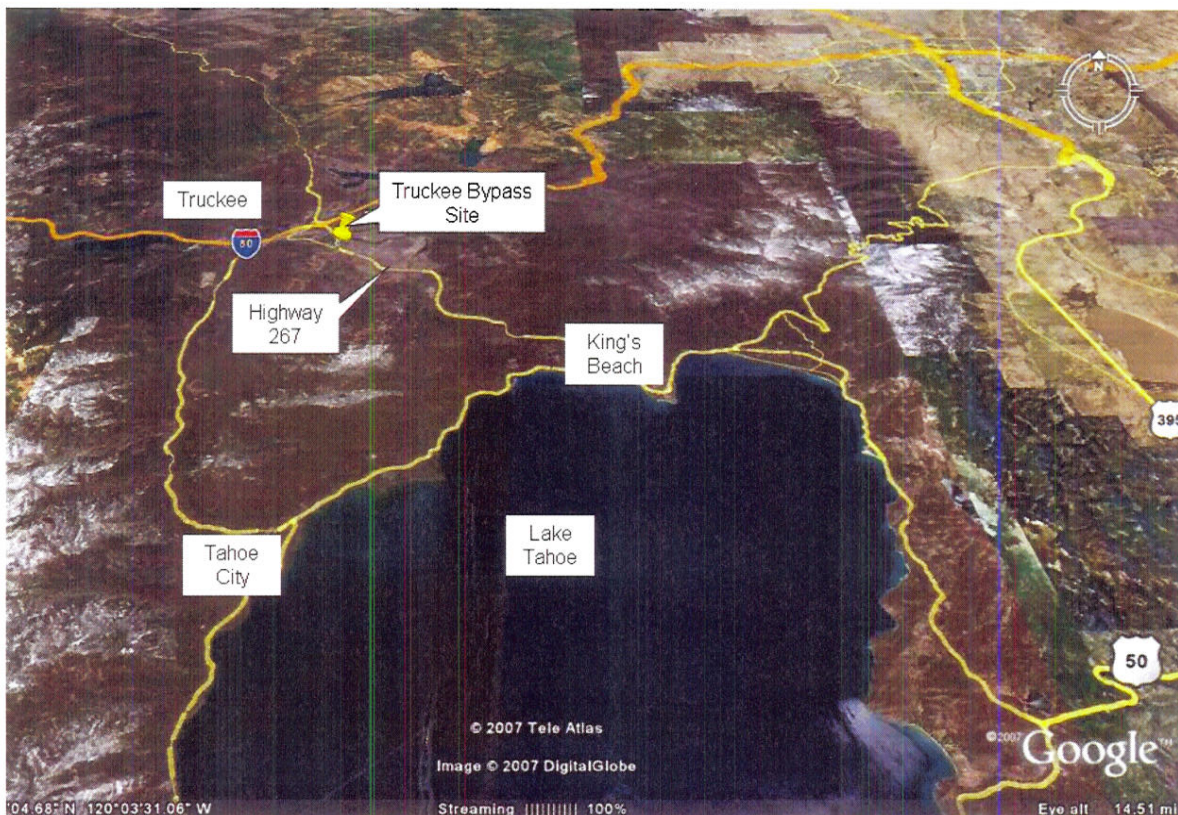


Figure 1. Satellite Map of the Truckee Bypass project area location. The project area is just north of Lake Tahoe, in California.



Figure 2. Satellite map of the test plots, the Caltrans irrigation plot, and the native reference plot locations within the Truckee Bypass project area.

PURPOSE

The specific project goals are outlined below. All plots can be divided into two categories: full treatment and surface treatment. Full treatment includes tilling or ripping of an organic amendment such as compost or woodchips, fertilizer and native seed addition, and native mulch application. Surface treatment does not include the incorporation of organic matter into the soil. It may include surface seeding or hydro mulching.

These treatments were studied to investigate:

- 1) the erosion control differences between full treatment and surface treatment plots
- 2) the effects of different seed rates and seed mixes on plant cover and composition
- 3) the effects of tilling versus ripping on soil density and infiltration

- 4) the effects of different types of organic matter (compost, tub grindings, and composted woodchips) on soil density, soil nutrient levels and availability, and plant growth
- 5) the effect of different Biosol fertilizer rates on plant growth and the nutrient status of the soil

SITE DESCRIPTION

The test plots are located on a northeast facing cut slope next to Highway 267, in Truckee, California (Figure 3). The site elevation is 5,765 feet (1,758 meters) above mean sea level (AMSL). The slope angle is between 20 and 25 degrees. Much of the topsoil was removed and the slopes were cut into the volcanic parent material sub-soil. These slopes have also been mechanically compacted by heavy machinery. The soil parent material is volcanic and is classified as a sandy loam with 66% sand, 18% silt, and 15% clay. The soil is very rocky with up to eighty percent coarse fragments (greater than ½ inch diameter) in some areas. The site is surrounded by local native vegetation consisting of an open Jeffrey pine (*Pinus jeffreyi*) canopy, with an under story of bitterbrush (*Purshia tridentata*) and Wyoming sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), and a few native bunchgrasses and forbs.

METHODS

Treatment Overview

Of the 14 plots, there are 12 test plots (1a-6b) that received different variations of the full treatment (Figure 3). These treatments will be explained in detail below. Two additional test plots did not receive full treatment. Plot “X” had been previously treated with the Caltrans Erosion Control Type D (EC Type D) specification. Plot “NT” received the same treatment as plot “X”, but in 2005, small, native shrubs were planted. None of the above described plots were irrigated. The Caltrans irrigated plot, which is located just north of the test plots, was treated in 2004 with the Caltrans EC Type D specification. Planting and site irrigation took place in 2005. The EC Type D specification included an initial hydroseed application of seed and fertilizer, followed by a surface application of compost to less than 1 inch deep. This was followed by an application of pine needle and woodchip mulch to a depth of 1 to 2 inches (2.54 to 5 cm) at the non-irrigated areas and 1 to 6 inches (2.54 to 15.2 cm) at the irrigated plot, and a final application of tackifier. The EC type D non-irrigated plot did receive initial irrigation in 2005. The irrigated plots received irrigation for the duration of the 2006 growing season, and for part of the 2007 growing season. In 2007, during sampling, the irrigation was not in use. The native reference site, located just off Highway 267 is undisturbed and was used as a baseline reference for all other treatments.

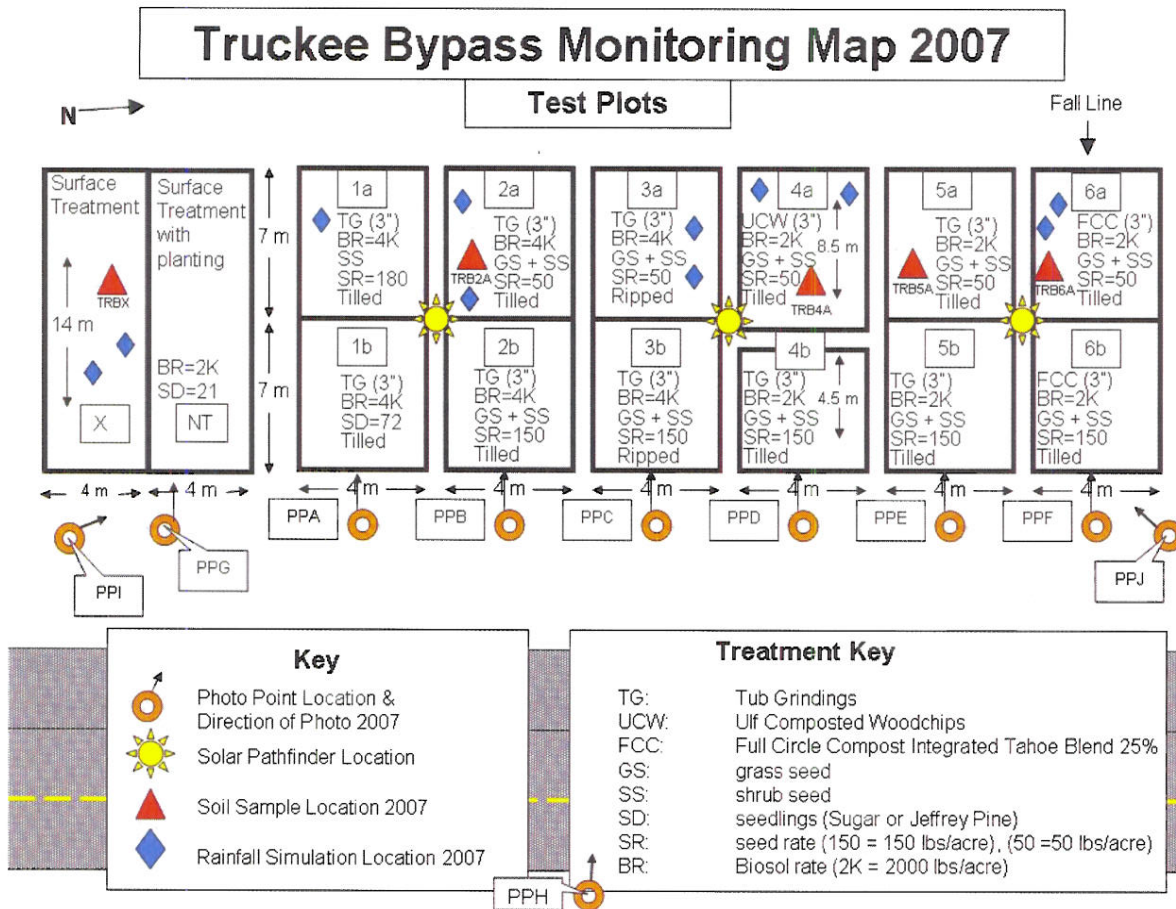


Figure 3. Map of the Truckee Bypass test plots with treatment key. Rainfall simulation, photo points, and soil sample, and Solar Pathfinder locations are marked.

Test Plot Treatments

Test plot treatments are presented in Table 1. Photos of the test plots before and after treatment are shown in Figure 4, Figure 5, and Figure 6. The native reference plot is shown in Figure 7.

Soil Loosening

Test plots 2a-6a were either tilled to a depth of 12 inches (30 cm) using a rubber-tracked excavator with a 24 inch (61 cm) bucket, or they were ripped to depth of 12 inches using tines mounted on the excavator bucket (Figure 3).

Table 1. Truckee Bypass Treatments.

Plot	Plot Name	Amendment	Soil Loosening	Biosol Rate (lbs/acre)	Seed Type	Seed Rate	Mulch
X	Surface Treatment	----	----	n/a	EC Type D	n/a	Pine needle and wood-chip mulch 1 - 2"
NT	Surface Treatment with planting	----	----	2,000	EC Type D, Seedlings	Seed rate n/a, 21 seedlings	Pine needle and wood-chip mulch 1 - 2"
IRR	Caltrans irrigation	----	----	n/a	EC Type D	n/a	Pine needle and wood-chip mulch 1 - 6"
1a		3" Tub Grindings	12" Tilled	4,000	Shrub only	180	Pine needles 2"
1b		3" Tub Grindings	12" Tilled	4,000	Seedlings	72 seedlings	Only surrounding seedlings
2a		3" Tub Grindings	12" Tilled	4,000	Grass and shrub seed	50 lbs/acre	Pine needles 2"
2b		3" Tub Grindings	12" Tilled	4,000	Grass and shrub seed	150 lbs/acre	Pine needles 2"
3a		3" Tub Grindings	12" Ripped	4,000	Grass and shrub seed	50 lbs/acre	Pine needles 2"
3b		3" Tub Grindings	12" Ripped	4,000	Grass and shrub seed	150 lbs/acre	Pine needles 2"
4a		3" Ulf Composted Woodchips	12" Tilled	2,000	Grass and shrub seed	50 lbs/acre	Pine needles 2"
4b		3" Tub Grindings	12" Tilled	2,000	Grass and shrub seed	150 lbs/acre	Pine needles 2"
5a		3" Tub Grindings	12" Tilled	2,000	Grass and shrub seed	50 lbs/acre	Pine needles 2"
5b		3" Tub Grindings	12" Tilled	2,000	Grass and shrub seed	150 lbs/acre	Pine needles 2"
6a		3" Compost	12" Tilled	2,000	Grass and shrub seed	50 lbs/acre	Pine needles 2"
6b		3" Compost	12" Tilled	2,000	Grass and shrub seed	150 lbs/acre	Pine needles 2"

n/a denotes that the information was not available.



Figure 4. Truckee Bypass test plots, pre-construction, 2005.



Figure 5. Truckee Bypass test plots, post-treatment, June, 2006.



Figure 6. Truckee Bypass test plots, 1 year following treatment, June 2007.



Figure 7. Truckee Bypass native reference plot, 2007.

Amendments

Tub Grindings

Type 1 tub grindings were obtained from the local landfill site and are composed of raw trees not processed construction wood. Type 1 tub grindings often include root material and the attached soil creating a material with higher potential nutrients than woodchips. Tub grindings are produced by a tub grinder that masticates the wood, rather than a chipper, which chips the material. This process results in a high surface area and long grindings, compared to woodchips. The tub grindings were spread to a depth of 3 inches (7.6 cm), which provided a total nitrogen content of approximately 139 lbs/acre (156 kg/ha).

Compost

The Integrated Tahoe Blend 25% was obtained from Full Circle compost (Minden, NV). It contains 25% humus fines of 3/8 inch (1 cm) or smaller and 75% compost wood overs. Wood overs (also called coarse overs) are the woody material remaining after the composting process that do not pass through the 3/8 inch diameter screen, and range in size from 3/8 of an inch to 3 inches (7.6 cm). The Integrated Tahoe Blend 25% spread to a depth of 3 inches (7.6 cm) provides a nitrogen equivalent of approximately 2,900 lbs/acre (3,250 kg/ha).

Composted Woodchips

The woodchips used at the Truckee Bypass site were composted for 2 years. A depth of 3 inches (7.6 cm) provides a nitrogen equivalent of approximately 715 lbs/acre (802 kg/ha).

Fertilizer

Following incorporation of amendments, Biosol, a slow release fertilizer, was applied and raked into the soil at a rate of either 2,000 lbs/acre (2,241 kg/ha) or 4,000 lbs/acre (4,483 kg/ha).

Seed

Suitable native perennial grasses and shrubs were seeded at a rate of either 50 lbs/acre (56 kg/ha) or 150 lbs/acre (168 kg/ha), and a shrub only seed mix was applied at a rate of 180 lbs/acre (209 kg/ha) (Figure 3, Table 2, and Table 3). Seed was not applied to plot 1b, but 72 shrub and tree seedlings were planted by hand at this plot (Table 4).

Table 2. Grass and shrub seed mix (plots 2-6)

Common Name	Scientific Name	% PLS
Mountain brome (Bromar)	<i>Bromus carinatus</i>	23%
Squirreltail	<i>Elymus elymoides</i>	21%
Snowbrush Ceanothus	<i>Ceanothus velutinus</i>	14%
Bitterbrush	<i>Purshia tridentata</i>	14%
Sulfur flower buckwheat	<i>Eriogonum umbellatum</i>	7%
Big mountain sagebrush	<i>Artemisia tridentata</i>	7%
Wax currant	<i>Ribes cereum</i>	7%
Western Needlegrass	<i>Achnatherum occidentale</i>	7%
Meadow Penstemon	<i>Penstemon rydbergii</i>	1%

Table 3. Shrub seed mix (plot 1a)

Common Name	Scientific Name	% PLS
Sulfur flower buckwheat	<i>Eriogonum umbellatum</i>	17%
Snowbrush Ceanothus	<i>Ceanothus velutinus</i>	17%
Meadow Penstemon	<i>Penstemon rydbergii</i>	17%
Big mountain sagebrush	<i>Artemisia tridentata</i>	17%
Bitterbrush	<i>Purshia tridentata</i>	17%
Wax currant	<i>Ribes cereum</i>	17%

Table 4. Seedling list (plot 1b and surface treatment with planting area)

Common Name	Scientific Name	# of seedlings planted
Mountain Pride	<i>Penstemon newberii</i>	23
Sugar or Jeffrey pine	<i>Pinus spp.</i>	20
Huckleberry Oak	<i>Quercus vacciniifolia</i>	10
Sulfur-flowered buckwheat	<i>Eriogonum umbellatum</i>	10
Mule's ear	<i>Wyethia mollis</i>	9
	Total	72

Table 5. Erosion Control Type D seed mix (Caltrans irrigated plot, the surface treatment plot (X), and the surface treatment with planting area (NT))

Common Name	Scientific Name
Squirreltail	<i>Elymus elymoides</i>
Blue wildrye	<i>Elymus glaucus</i>
Idaho fescue	<i>Festuca idahoensis</i>
Mountain brome	<i>Bromus carinatus</i>
Spanish clover	<i>Lotus purshianus</i>
Lupine species	<i>Lupinus grayii and/or breweri</i>
Yarrow	<i>Achillea millefolium</i>
Sulfur flower buckwheat	<i>Eriogonum umbellatum</i>
* seed rate not available for this seed mix.	

Mulch

Mulch was spread evenly to achieve 99% cover at a depth of 2 inches on all full treatment test plots, except plot 1b. On plot 1b, mulch was only spread around each seedling.

Monitoring

The test plots and the Caltrans irrigated plot were both monitored in 2006 and 2007. Additionally, in 2007, monitoring was conducted at a native reference site. All monitoring was conducted in metric units, while treatment applications were calculated in English units. In the text, both metric and English units are given. Some tables, such as those for the seed mixes are only presented in English units.

Cover

Cover point monitoring was conducted at the Truckee Bypass test plots and the Caltrans irrigated plot in August of 2006 and June of 2007. Cover was measured at the native reference site in June of 2007. Cover was measured using the cover point method along randomly located transects.¹ The cover pointer consists of a metal rod with a laser pointer mounted 3.3 feet (1 meter) high. After the rod is leveled in all directions, the button on the laser pointer was depressed and two cover measurements were recorded (Figure 8 and Figure 9):

- 1) the first hit cover, which represents the first object intercepted starting from a height of 3.3 feet (1 meter) above the ground and
- 2) the ground cover hit.

The first hit cover measures the foliar cover by plants (leaves and stems). It does not measure the part of the plant actually rooted in the ground. The ground cover hit measures whatever is lying on the ground or rooted in the ground (i.e litter/mulch, bare ground, basal (or rooted) plant cover, rock and woody debris).

¹ Hogan, Michael. Luther Pass Monitoring Report: Plant and Soil Cover Monitoring for Evaluating Sediment Source Control Success in the Lake Tahoe Basin. 2003. South Lake Tahoe, CA, Lahontan Regional Water Quality Control Board.



Figure 8. Cover pointer in use along transects.



Figure 9. Cover pointer rod with first hit foliar and ground cover hit by the laser pointer. The laser pointer hits are circled in red. The first cover hit is a native grass and the ground cover hit is pine needle mulch.

Total ground cover comprises all cover other than bare ground. Plant cover both on the ground and foliar was recorded by species and then organized into cover groups based on four categories: lifeform (herbaceous/woody), perennial/annual, native/alien (2007 only), and seeded/volunteer (2007 only). Perennial herbaceous species includes seeded grasses, native grasses and forbs and any non-native perennial species. Annual herbaceous species include native annuals such as knotweed (*Polygonum* sp.) and invasive species such as cheatgrass (*Bromus tectorum*). Woody species are any tree and shrub species of interest native or introduced. Each species was then classified based on whether it is native to the Tahoe area, and whether it was seeded during treatment. Data is also presented on the amount of cover by species. Species of interest are species that were seeded and problem species such as cheatgrass. An ocular estimate of cover at each plot was also recorded and includes many species not hit using cover point sampling. The species list as well as the ocular estimates of cover by species is presented in Appendix A.

Soil and Site Physical Conditions

Soil Density

In 2006 and 2007, soil density and soil moisture were measured along the same transects as the cover point data for all of the plots. A cone penetrometer was used to measure soil density. The cone penetrometer with a ½ inch diameter tip was pushed straight down into the soil until a maximum pressure of 350 pounds per square inch (psi) (2,411 kPa) was reached (Figure 10 and Figure 11). The depth at which that pressure was reached was recorded as the

depth to refusal (DTR). These depth measurements were used as an index for soil density and infiltration capacity.

When soil moisture content increases, a soils resistance to the penetrometer decreases. Therefore is most useful and informative to compare penetrometer DTR measurements that were collected on soil that have similar moisture levels. DTR values collected in August 2006 at the non-irrigated sites (low soil moisture) and could not be compared to those at the irrigated site (high soil moisture). To resolve the difference between plots with different soil moistures, further penetrometer sampling was conducted in December of 2006, once irrigation had been turned off and there had been several soaking rains. At that time, soil moisture values were similar between the different plot areas.

In 2007, irrigation was not applied to the Caltrans “irrigated” plot for 6 weeks prior to sampling, therefore the soil moisture values at the Caltrans irrigated plot were similar to the other sampling areas. Penetrometer values could be compared across all sites in 2007.



Figure 10. Photo of a cone penetrometer dial, showing pressure applied in pounds per square inch.

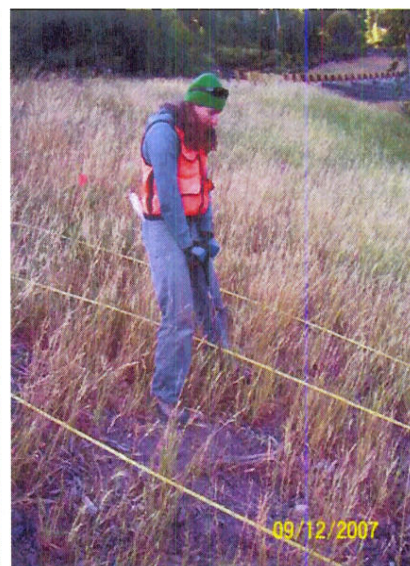


Figure 11. Photo of conducting cone penetrometer readings along transects.

Soil Moisture

A hydrometer was used to measure volumetric soil moisture content adjacent to the penetrometer readings at a depth of 4.7 inches (12 cm) (Figure 12). In 2006, additional soil density and soil moisture data was collected in December after several soaking rainfalls to investigate the relationship between soil moisture and soil density.

Soil Strength

In 2007, soil strength was tested along cover point transects in the same manner as soil density and soil moisture. A hand-held soil strength shear vane with 1.5 inch (3.8 cm) long blades was pushed into the soil to a depth of 3 inches (7.6 cm) and turned until the soil could no longer resist the force exerted by the blades and the soil structure either fractured or deformed (Figure 13). This force was then recorded as the “shear stress” in kilopascals (kPa). Forty kPa is the maximum force the shear vane can measure. Any values above 40 kPa were recorded as 40 kPa and noted as such.

This method of determining shear strength has been regularly used in agricultural soils and various laboratory tests.² This method of testing soil shear strength has not been applied to many forest soils. Dense soil and the high concentration of coarse fragments in the soil prevented soil strength measurements at some plots (X and NT). At other plots, the shear strength measurements may have been artificially high from the rocky nature of the soil. When the blade touches a rock, the rock will not fracture or deform as soil would, therefore, the highest soil strength will be recorded.

Solar Radiation

In 2006, solar radiation measurements were taken throughout the Truckee Bypass test plots, as well as at the Caltrans irrigated plot. These measurements were taken using a Solar Pathfinder (Figure 14). Since there was no change in solar obstructions at the test plots, the solar pathfinder data was not collected again in 2007. However, in 2007, solar radiation was recorded at the native site. Since solar input affects evaporation rates and soil temperature, which may affect time of seed germination, germination rate, rate of plant growth and soil microbial activity, it is an important variable to consider when monitoring plant growth and soil development.



Figure 12. Conducting soil moisture readings along transects.



Figure 13. Soil shear strength tester in use.



Figure 14. Solar pathfinder in use.

² Tengbeh, G.T. 1993. The Effect of Grass Roots on Shear Strength Variations with Moisture Content. *Soil Technology*. Vol. 6. pp. 287-295.

Soil Nutrient Analysis

In 2006 and 2007, soil samples were taken from test plots 2a, 4a, 5a, 6a, the irrigated plot, and the surface treatment plot (Table 1 and Figure 3). In 2007, a soil sample was also taken from the native plot. Three soil sub-samples were taken from each location of the mineral soil beneath any mulch layer to a depth of 12 inches (30 cm). These sub-samples were combined and sieved to remove any material larger than 0.08 inches (2 mm) in diameter, and then sent to A&L Laboratories (Modesto, CA) for the S3C nutrient suite, total Kjeldahl nitrogen (TKN), and organic matter analysis. A control sample and a treatment sample were analyzed for particle size distribution.



Figure 15. Soil sub-sample collection.

Rainfall Simulation

In 2006, rainfall simulation was conducted on test plots 1a, 2a, 3a, 4a, 6a, the surface treatment planting plot (NT), the irrigated plot, and the surface treatment plot (X). In 2007, rainfall simulation was conducted on the same test plots; 1a, 2a, 3a, 4a, 6a, the irrigated plot, the surface treatment plot (NT), and the newly established native plot (Figure 3). The surface treatment plot with planting did not receive rainfall simulation in 2007. The rainfall simulator “rains” on a square plot from a height of 3.3 feet (1 meter) (Figure 16 and Figure 17). The rate of rainfall is controlled, and runoff is collected from a trough at the bottom of a 0.6 square meter (6.5 square feet) frame that is pounded into the ground. The volume of water collected is measured and the volume of infiltration is calculated by subtracting the volume of runoff from the total volume of water applied to the plot. If runoff was not observed during the first 30 minutes, the simulation was stopped. The collected runoff samples were then analyzed for the amount of sediment, which is presented as the average steady state sediment yield.

The cone penetrometer was used to record the depth to refusal (DTR) in the area of the runoff frames before rainfall simulations. The 2006 DTR pre-rainfall values were taken at a maximum pressure of 250 psi (1,724 kPa) and the 2007 DTR values were taken at 350 psi (2,413 kPa). Soil moisture was also measured in each runoff frame prior to conducting the rainfall simulations. After rainfall simulation, at least three holes were dug with a trowel to determine the depth to wetting front, which shows how deeply water infiltrated within the soil. In 2007, at least nine holes were dug to measure the depth to wetting front.

Different rainfall rates were applied to different plots depending on their propensity to runoff. In 2006, three rainfall rates were applied to the plots: 2.8 inches/hour (72mm/hr) at the Caltrans irrigation plot and the surface treatment (X) plot, 3.3 inches/hour (84 mm/hr) at the surface treatment plot with planting (NT), and 4.7 inches/hour (120 mm/hr) at the tilled test plots. In 2007, the following rainfall rates were applied: 4.7 inches/hour (120 mm/hr) at the tilled test plots, 2.8 inches/hour (72 mm/hr) at the surface treatment plot (X), and 4.1 inches/hour (104 mm/hr) at the native and Caltrans irrigated sites. The lowest rainfall rate, 2.8 inches/hour, is in excess of the 20 year, one hour 'design storm' for the Truckee-Tahoe area, which is between 0.7 to 1.0 inches/hour (18.0 to 24.5 mm/hour). The design storm is used to design most storm water routing plans.

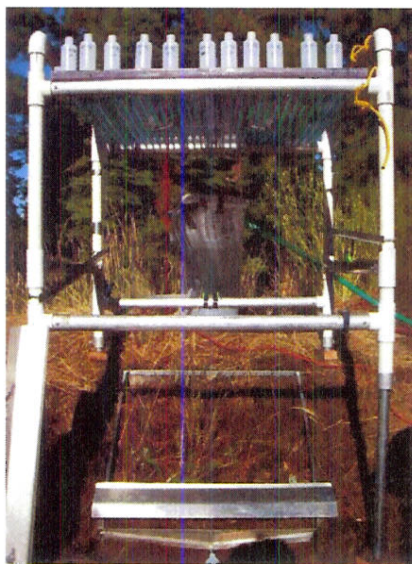


Figure 16. Photo of the rainfall simulator and frame.



Figure 17. Photo of rainfall simulation at Truckee Bypass test plots, June 2006.

Statistical Analysis

Several different statistical tests were used to determine difference between treatments. The type of test employed depended on the number of variables tested and the normality of the sample. An Analysis of Variance (ANOVA) was

used to investigate whether there were any significant differences in plant cover, soil moisture, or soil density among plots with different treatments. An ANOVA sorts data by groups. In this case, data was sorted by amendment type (tub grindings, compost, and composted woodchips). ANOVA is typically used with three or more groups.³

If a difference was detected using the ANOVA test, the student's t-test, the Tukey test, or the Mann-Whitney test was used to further investigate differences between two sub-groups or sample sets within the larger group. The Mann-Whitney test is a non-parametric test that can be applied to data sets with non-normal distributions. Non-normal distributions are common within small data sets. Some the sample sizes at the Truckee Bypass test plots were small ($n = 3$), making it necessary to use a non-parametric test.

RESULTS/DISCUSSION

Rainfall

Surface treatments without soil loosening and amendments had sediment yields that were higher and infiltration rates that were 1.4 times lower than the full treatment plots with soil loosening and amendments (Figure 18 and Figure 19). In 2006 and 2007, sediment yields ranged from 5 to 286 lbs/acre/in (2.2 to 126 kg/ha/cm) at plots without soil loosening, while plots with amendments and soil loosening did not produce any sediment. In 2006, the surface treatment plot with planting had a steady state infiltration rate of 3.8 inches/hour (97 mm/hr) at a rainfall rate of 4.7 inches/hour (120 mm/hr). The sediment yield was 286 lbs/acre/inch (123 kg/ha/cm, Figure 18). This was the highest observed sediment yield when compared to all the simulations at the Truckee Bypass. The Caltrans irrigated plot had a two-year average infiltration rate of 3.4 inches/hour (86 mm/hr) and a two-year average sediment yield of 110 lbs/acre/in (49 kg/ha/cm, Figure 18 and Figure 19).

In 2006, the surface treatment plots had the lowest infiltration rate (2.6 inches/hour or 6.6 cm/hr) at an average rainfall rate of 3.3 inches/hour (84 mm/hr), and generated 161 lbs/acre/inch (67.1 kg/ha/cm) of sediment (Figure 19). In 2007, this plot received an average rainfall rate of 2.8 inches/hour (72 mm/hr) and had an infiltration rate of 2.6 inches/hour (6.6 cm/hr) with a sediment yield of 86 lbs/acre/inch (38 kg/ha/cm) (Figure 19).

The native plot had a steady state infiltration rate of 3.9 inches/hour (99 mm/hr) and a sediment yield of 5.2 lbs/acre/inch (2 kg/ha/cm).

³ Zar, J.H. Biostatistical Analysis 4th Edition 1999. Prentice Hall Press, Upper Saddle River, New Jersey.

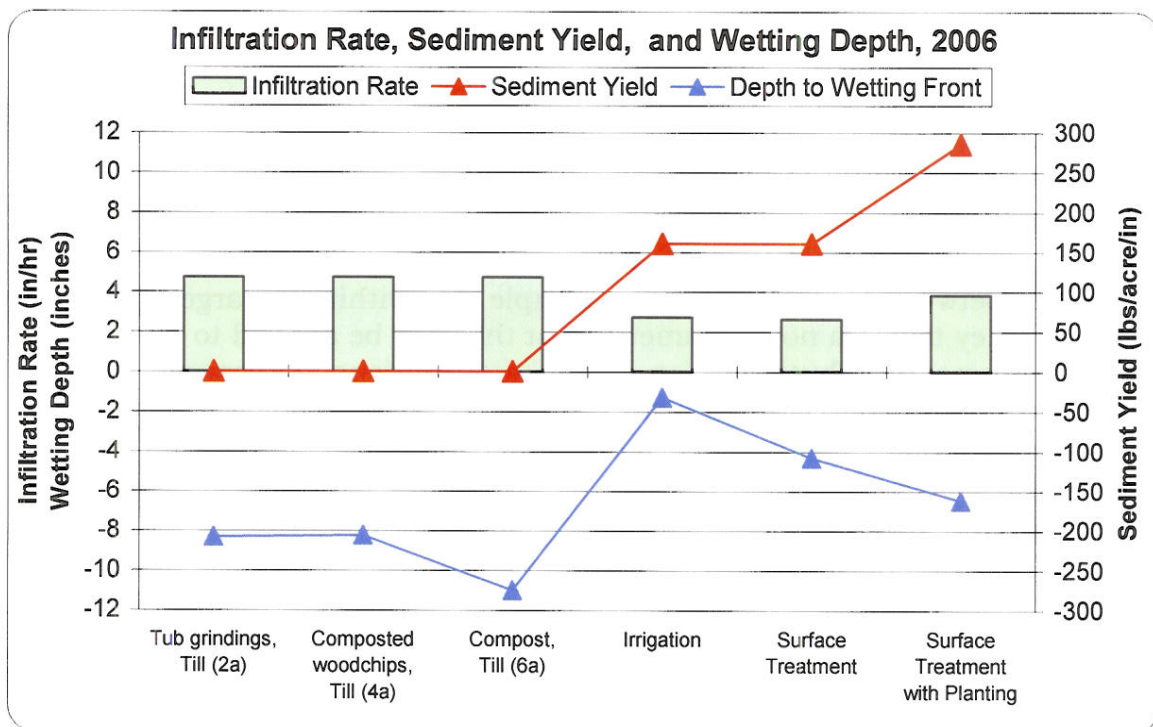


Figure 18. Infiltration Rate, Sediment Yield, and Wetting Depth, 2006. The plots that had the highest infiltration and lowest sediment yields also had the deepest wetting depths.

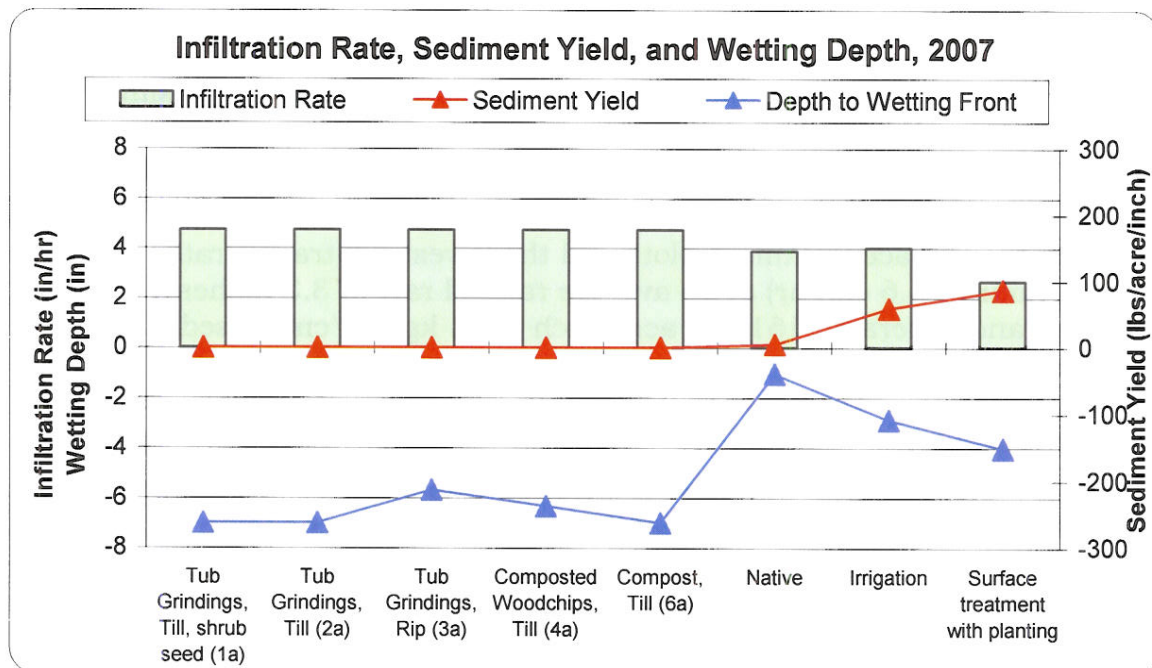


Figure 19. Infiltration Rate, Sediment Yield, Wetting Depth, 2007. The plots with highest infiltration rates and the lowest sediment yield had greatest wetting depths.

There was no difference in infiltration rates or sediment yields between amendment types, seed rates, soil loosening method, or Biosol rates (Figure 18 and Figure 19). Actual infiltration rates and sediment yields could not be compared among these treatment types since none of the full treatment plots produced runoff at the rainfall rate of 4.7 inches/hour (120 mm/hr).

Plots with higher sediment yields and lower infiltration rates (full treatment plots) had wetting depths that were at least 1.6 times deeper than those at plots with high sediment yields and low infiltration rates (surface treatment plots, Figure 18 and Figure 19). The average wetting depth for the full treatment plots that did not produce any sediment was greater than 8 inches, while average wetting depth for the surface treatment plots was less than 5 inches.

In 2007, the wetting depth at the ripped plots was 1.5 times shallower than the wetting depth at the tilled plots with the same soil amendment (Figure 19). The wetting depth at ripped plots was less than 4 inches, while the wetting depth at tilled plots was greater than 6 inches.

The comparatively low infiltration rate and high sediment yield at the irrigated plot may be a result of the steeper slope angle (Table 6). It has been found in other studies that there is a weak, but significant relationship between sediment yield and percent slope for local volcanic soils. The steeper slopes generally yield more sediment when all other factor are equal.⁴ The difference in slope between the Caltrans irrigated plot and all other plots may have affected the runoff rate and sediment yield; however, the lower rainfall rate applied to this plot may have offset the effect of slope.

Table 6. Average frame slopes at the Truckee Bypass test areas.

Test Area	Plot code(s)	Slope range (%)
Tilling/ripping test plots	2a, 3a, 4a, 6a	21-31
Surface treatment and surface treatment with planting	X, NT	24-28
Native reference	N	29
Caltrans irrigation	IRR	44-48

Soil Density and Soil Moisture

Penetrometer values can only be compared between areas when soil moisture levels are consistent. In August and December 2006, soil moisture at all the non-irrigated test plots was significantly different from the soil moisture at the Caltrans irrigated plot (Figure 20 and Table 7). These large differences did not allow for comparison between the test plots and the irrigation plot in 2006.

⁴ Grismer and Ellis. (2004) Erosion Control Reduces Fine Particles in Runoff to Lake Tahoe. *California Agriculture* 60(2): 72 – 75.

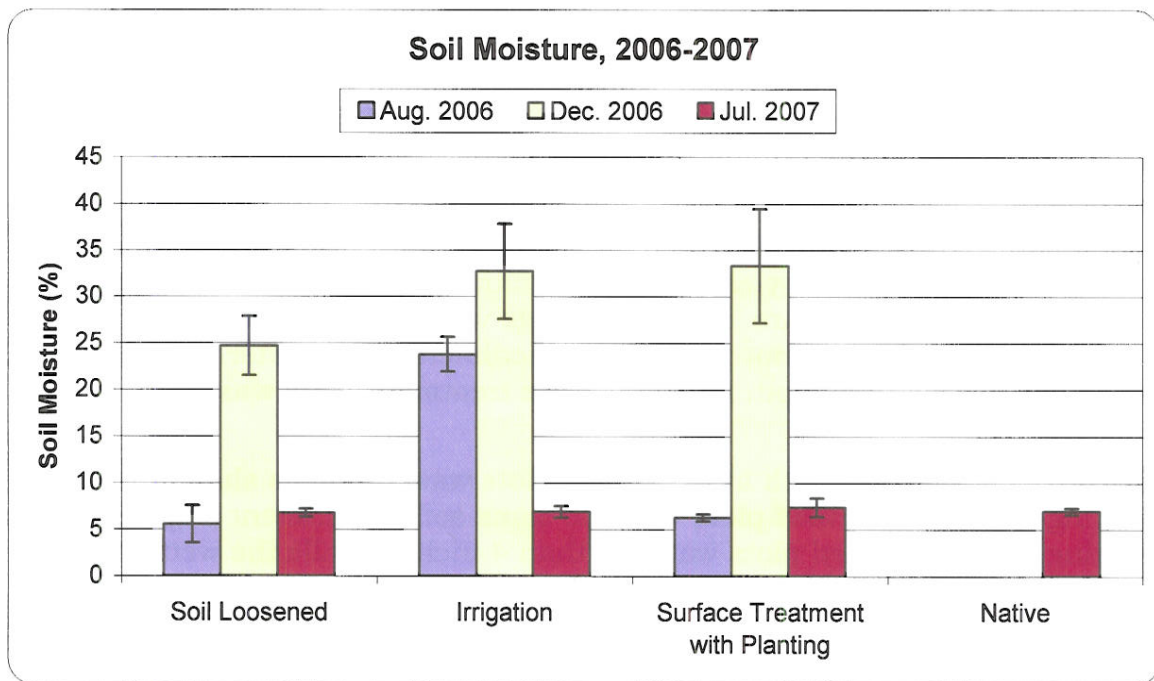


Figure 20. Soil Moisture, 2006-2007. In 2006, soil moisture values were not consistent across treatment types and therefore penetrometer depths could not be compared across all types. In 2007, soil moisture values were consistent, allowing for comparison of penetrometer values. Error bars denote one standard deviation above and below the mean.

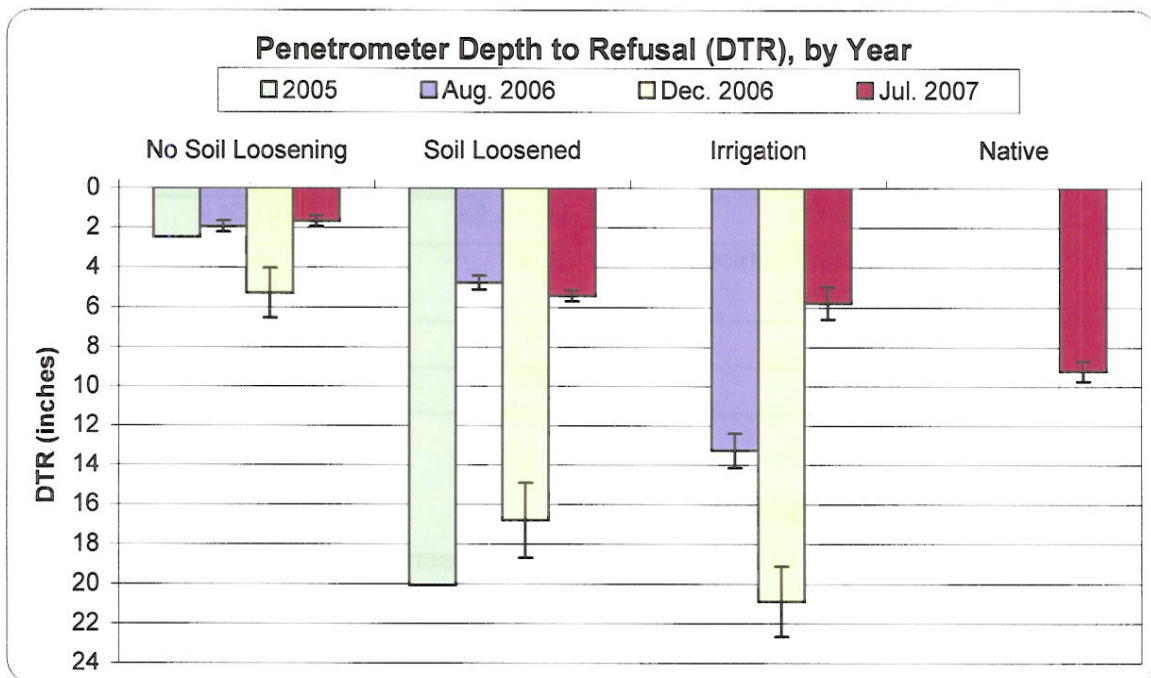


Figure 21. Penetrometer Depth to Refusal (DTR) by Year. Error bars denote one standard deviation above and below the mean.

In 2006, soil loosened (tilled or ripped) plots had DTRs that were approximately 2.5 times deeper than at the surface treatment plots without irrigation. The plots with soil loosening had DTRs that were greater than 16 inches, while the surface treatment plots had DTRs less than 6 inches (Figure 21).

In 2007, soil loosened plots had DTRs that were similar to DTRs at the irrigated plots and approximately 3 times deeper than those at the surface treatment plots (Figure 21). The DTRs at the soil loosened plots and the irrigated plots were deeper than 5 inches, while the surface treatment plots without soil loosening had DTRs that were shallower than 2 inches

There was no difference in soil density between ripped plots and tilled plots (Figure 21).

Soil Shear Strength

All plots had similar shear strength values that were comparable to those at the native plot (Figure 22). Shear strength values range from 32 to 37 kPa at the test plots and the irrigation plot, while the native site had a shear strength of 32 kPa.

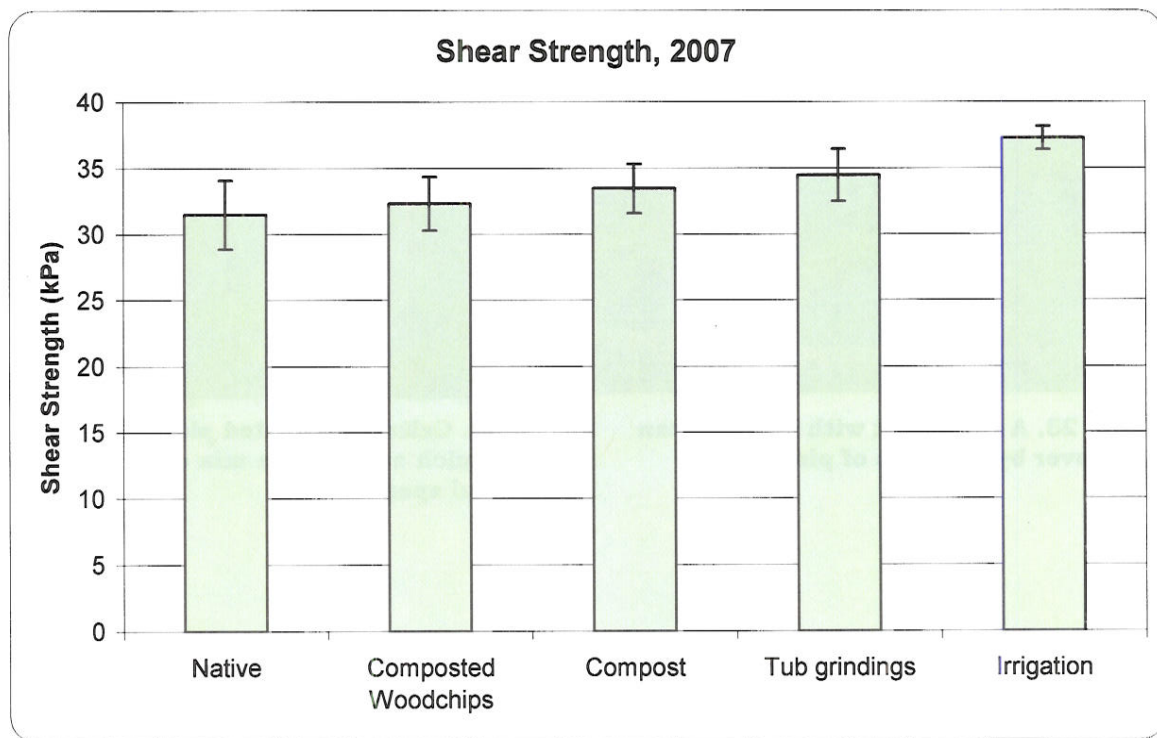


Figure 22. Shear Strength, 2007. No values were recorded at the surface treatment plots because the shear vane could not penetrate deep enough into the high density soil. Error bars denote one standard deviation above and below the mean.

Cover

Mulch Cover

In 2006 and 2007, plots with mulch cover greater than 89%, which included all full treatment plots, did not produce sediment (Figure 18, Figure 19, Figure 25, and Figure 26).

In 2006 and 2007, all of the surface treatment plots, which had mulch cover that ranged from 50 to 72%, produced sediment (Figure 18, Figure 19, Figure 25, and Figure 26). Mulch cover at the surface treatment plots, which had a sediment yield of 161 lbs/acre/in (71 kg/ha/cm) in 2006 and 86 lbs/acre/in (40 kg/ha/cm) in 2007 was approximately 65% in 2006 and 50% in 2007.

Cover by mulch at the surface treatment plot with planting, which had a sediment yield of 278 lbs/acre/inch (123 kg/ha/cm), was 51% in 2006. The irrigated plot, which produced 152 lbs/acre/in (67.1 kg/ha/cm) had 72% cover by mulch in 2006 and 70% cover in 2007. Mulch cover has also been related to sediment reduction in past research.⁵



Figure 23. A tilled plot with greater than 90% cover by 2 inches of pine needle mulch.



Figure 24. Caltrans irrigated plot, showing patchy mulch cover and a mix of perennial and annual species.

⁵ Grismer, ME, Hogan, MP. 2004. Evaluation of revegetation/mulch erosion control using simulated rainfall in the Lake Tahoe basin: 1. Method Assessment. *Land Degrad. & Develop.* 13:573-578.

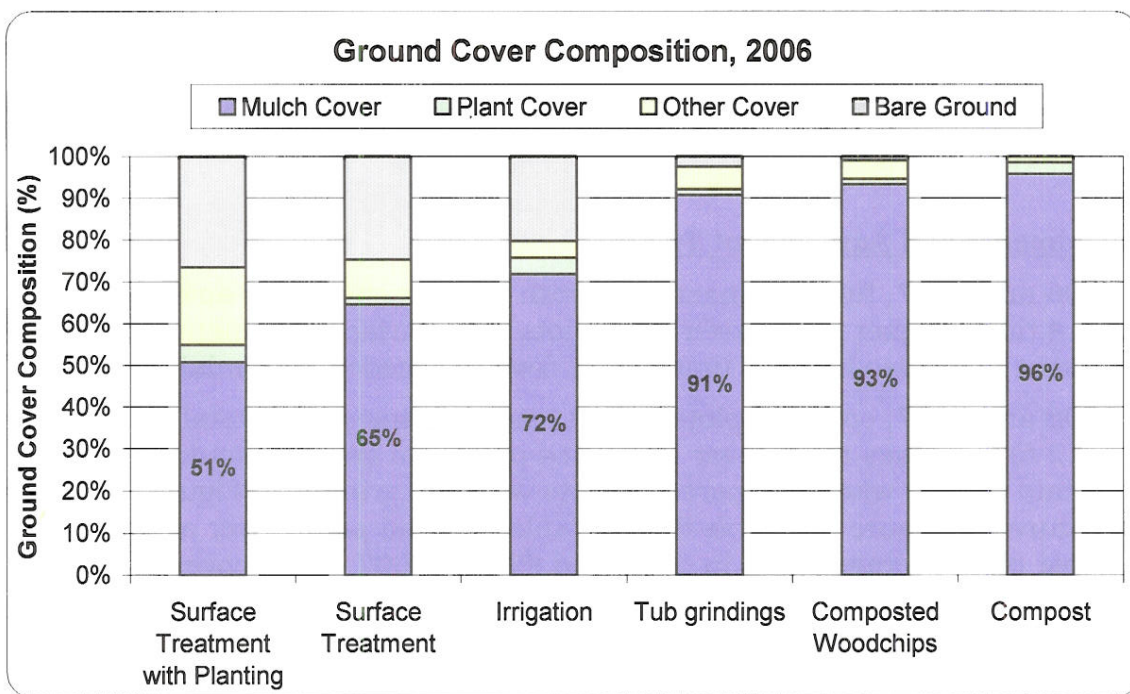


Figure 25. Ground Cover Composition, 2006. All full treatment sites had high mulch cover while all surface treatment plots had low mulch cover.

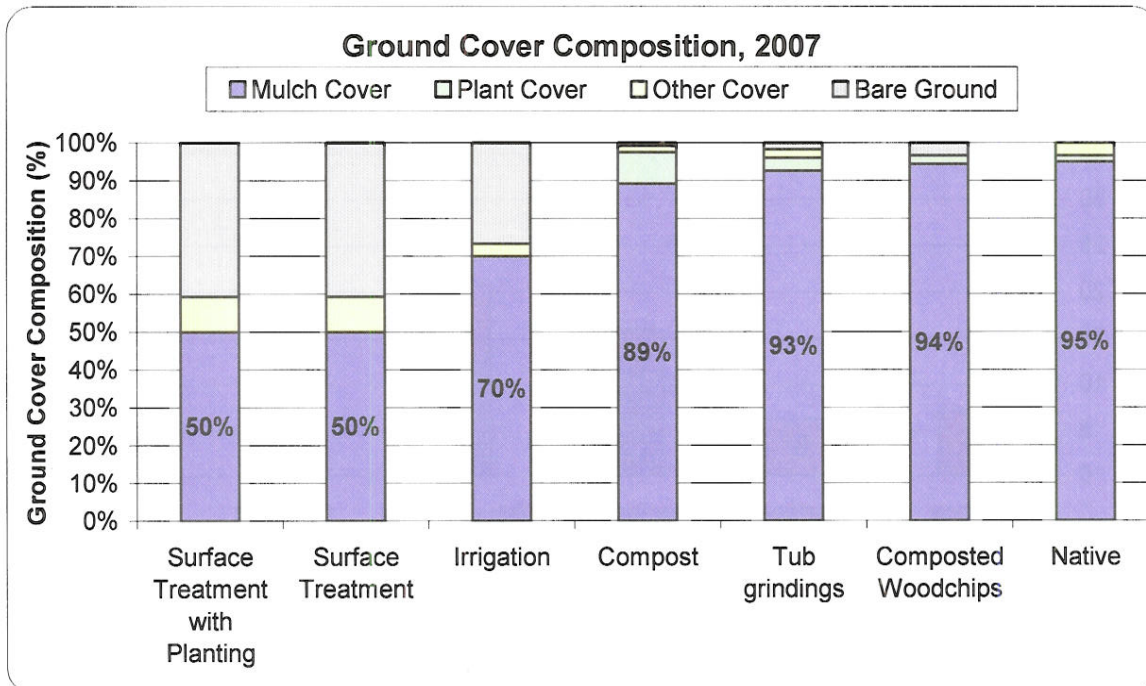


Figure 26. Ground Cover Composition, 2007. All full treatment sites had high mulch cover while all surface treatment plots had low mulch cover.

Plant Cover and Composition

Findings are categorized by amendment and amendment types, soil loosening method, Biosol rates, seed rates and types, irrigation, and yearly variations. All statistics are presented in the tables at the end of this section.

Amendments and Amendment Types

In 2006 and 2007, full treatment plots with soil loosening and amendments had 3.4 times higher plant cover than plots with surface treatment. The full treatment plots also had 8.8 times more cover by seeded perennial species.

In 2006 and 2007, compost plots had at least 1.7 times more total plant cover and 2.2 to 2.7 times more cover by seeded perennial grasses (squirreltail and mountain brome) when compared to plots with tub grindings (Figure 27, Figure 28, Figure 29, Figure 30, Table 8, and Table 9). Total plant cover at the compost plots averaged 39% in 2006 and 49% in 2007, while cover by seeded species was 32% in 2006 and 44% in 2007. In comparison, total plant cover at tub grindings plots was 22% in 2006 and 21% in 2007, while cover by seeded species ranged from 12 to 20%.

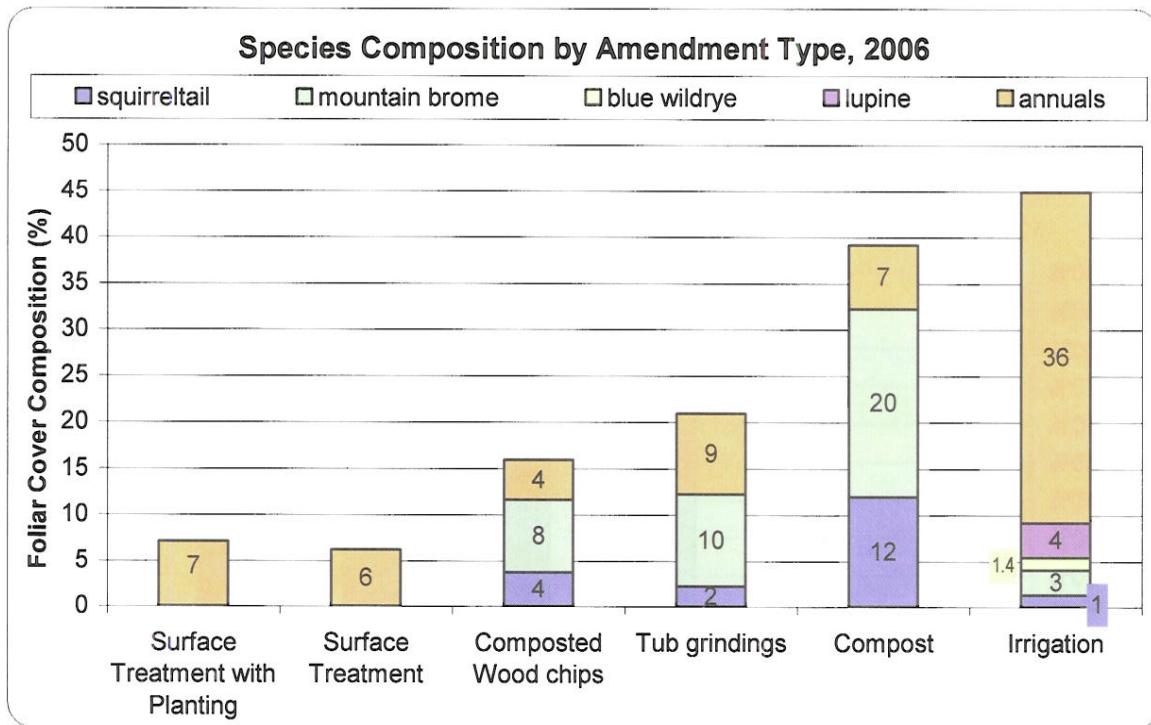


Figure 27. Species Composition by Amendment Type, 2006. Annual species at the irrigated plot was mostly seeded Spanish clover. The highest cheatgrass proportion was found at the tub grinding plots, but was less than 5% on average.

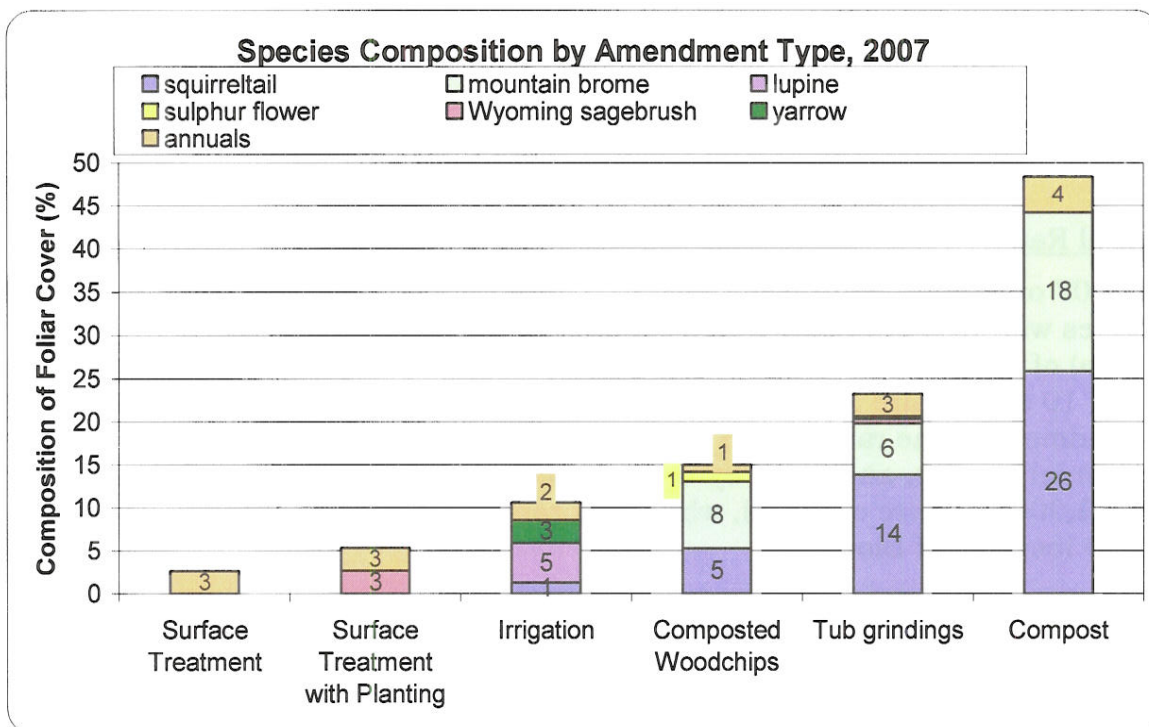


Figure 28. Species Composition by Amendment Type, 2007. Annual species at Caltrans irrigated plot were mostly seeded Spanish clover. The highest cheatgrass proportion was found at the tub grindings plots, but was less than 5% on average.



Figure 29. Truckee Bypass test plots 6a and 6b. In 2006, the plots (amended with compost) had greater than 25% cover by seeded grasses.



Figure 30. Truckee Bypass test plots 6a and 6b. In 2007, plots (amended with compost) had on average 44% cover by seeded grasses.

Soil Loosening Method

There was no significant difference in total plant cover for ripped plots versus tilled plots in 2006 or 2007. Both tilled and ripped plots had total plant cover that ranged from 15 to 47%.

Biosol Rates

In 2007 only, total plant cover, cover by perennial species, and cover by seeded species was approximately 2 times higher in plots with 2,000 lbs/acre (2,250 kg/ha) of Biosol when compared to plots with 4,000 lbs/acre (4,483 kg/ha, Table 10 and Figure 31). These differences existed regardless of the type of amendment or the rate of seed applied. The total plant cover, cover by perennial species, and cover by seeded species ranged from 27 to 32% at plots with 2,000 lbs/acre of Biosol, while they ranged from 14 to 17% at plots with 4,000 lbs/acre of Biosol.

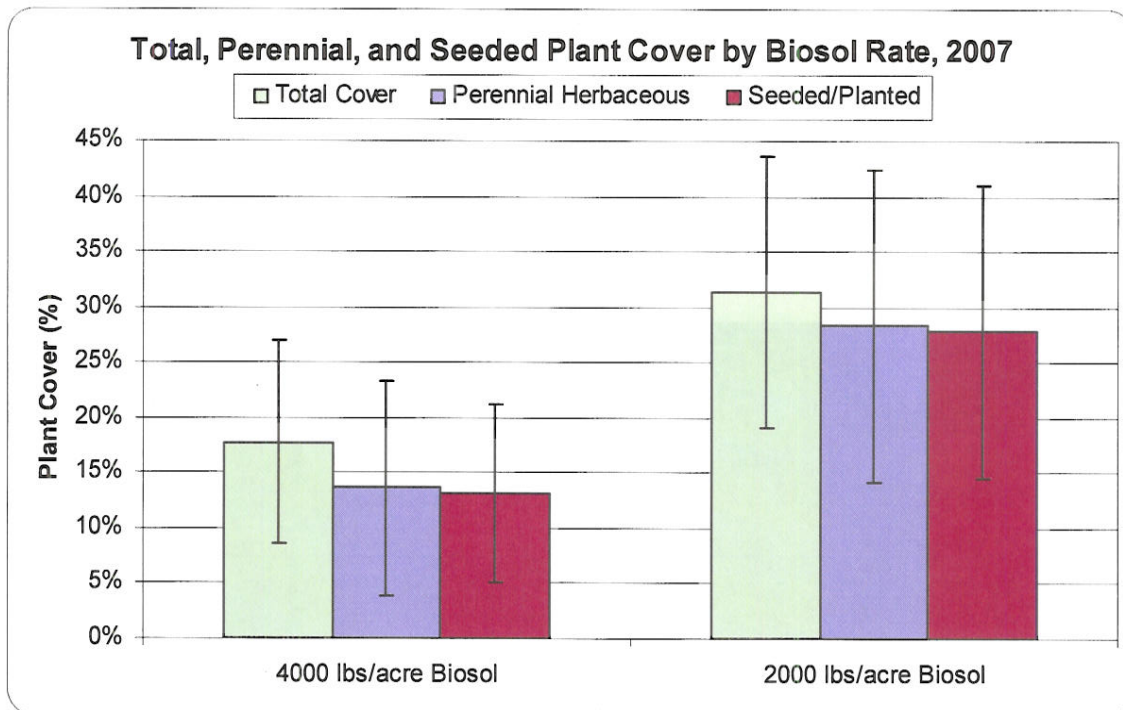


Figure 31. Total, Perennial, and Seeded Plant Cover by Biosol Rate, 2007. Note higher average cover all categories of plant cover with a 2,000 lbs/acre Biosol rate.

Seed Rates and Types

In both 2006 and 2007, the plot with the shrub only seed mix (1a) had 5 to 10 times less cover by perennial species and 16 to 23 times less cover by seeded species when compared to plots that received the mix primarily composed of grasses (Figure 32, Figure 33, and Figure 34 and Table 10). In 2007, the plot

with the shrub only seed mix had 1% cover by seeded species, compared to 16 to 23% cover by seeded species at plots with the mix composed of primarily grass. In 2006 and 2007, the plot with the shrub only seed mix had 2 to 3% cover by perennial species, while the plots with grass dominated mix had 14 to 24% cover by perennial species.

Plots with the higher seed rate (150 lbs/acre) supported slightly higher plant cover by perennial species and seeded species. In 2007, plots with the higher seed rate had 1.1 times more cover by perennial species and 1.2 times more cover by seeded species on average compared to plots with the lower seed rate (50 lbs/acre, Figure 34). In 2007, the plots with the higher seed rate had on average 23% cover by perennial species and 21% cover by seeded species. In 2007, the plots with the lower seed rate had on average 17% cover by perennial species and 16% cover by seeded species.

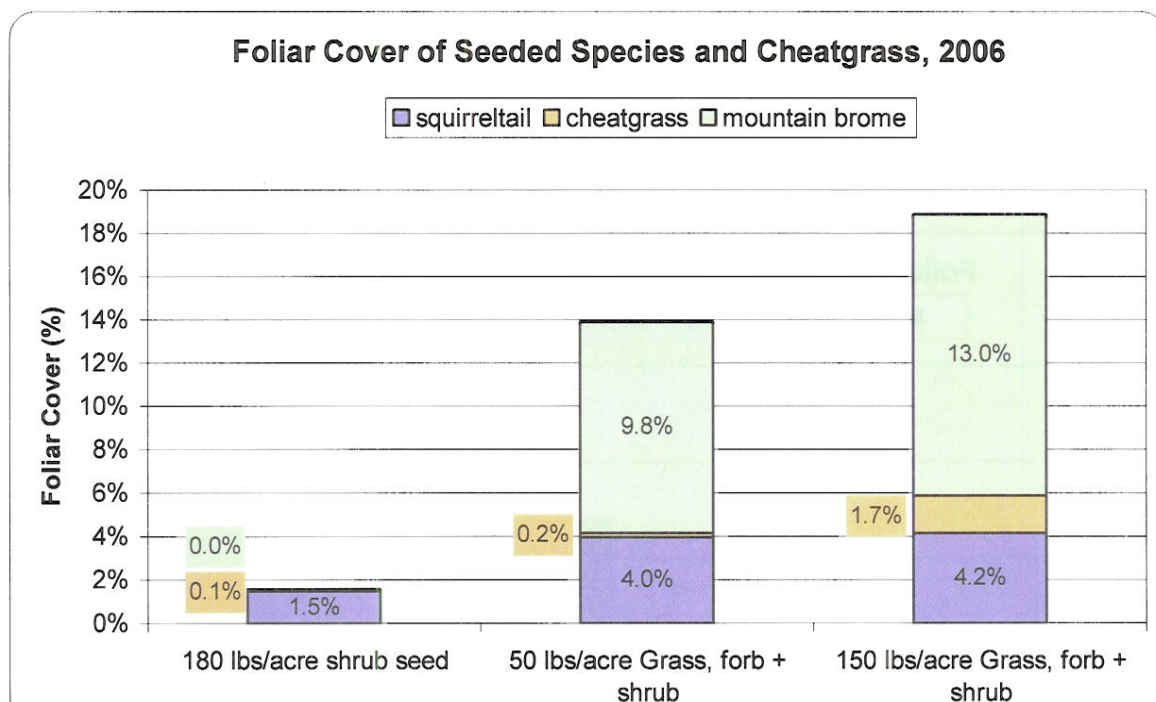


Figure 32. Foliar Cover of Seeded Species and Cheatgrass, 2006. There is higher cover by seeded species in the plots with the higher seed rate and more diverse seed mix; however, there is also higher cover by cheatgrass.

Irrigation

Most of the plant cover at the irrigated site was dependent on irrigation for growth, while the amended test plots maintained perennial plant growth without irrigation. In 2006, the irrigated plot had the highest total cover (48%) when compared to the plots with compost (39%), tub grindings (21%), composted woodchips (16%), or without amendments (6 to 7%). However, most

of the cover at the irrigated plot was by Spanish clover, an annual species with shallow roots (Figure 27). In 2007, once irrigation had been removed, the annual cover decreased markedly, thereby reducing the total plant cover at the irrigated site from 48% to 12%, while the cover at the other amended plots remained consistent (Figure 28).

Yearly Variations

Between 2006 and 2007, cover by mountain brome decreased by 1 to 4% at each plot, while cover by squirreltail increased by 1 to 14% at each plot (Figure 27 and Figure 28). In 2006, the cover by mountain brome ranged from 3 to 20%, while in 2007 it ranged from 8 to 18%. In 2006, cover by squirreltail ranged from 1 to 12%, while in 2007 it ranged from 1 to 26%. This trend was observed also at other test plot areas and can most likely be attributed to the much lower annual precipitation in 2007 versus 2006.

Despite the lower annual precipitation, cover by desirable perennial species at soil loosened test plots was on average 1.2 times higher in 2007 than in 2006 (Figure 27, Figure 28, Figure 32, and Figure 33). The cover by perennial species ranged from 14 to 19% in 2006 and 17 to 24% in 2007.

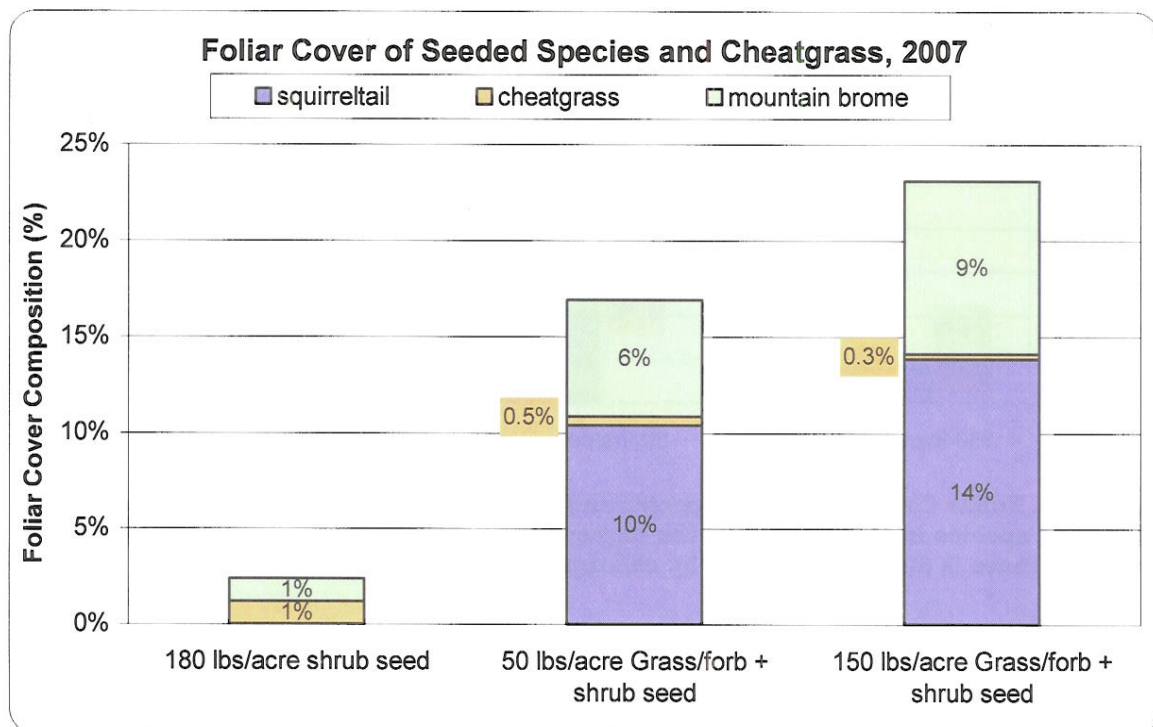


Figure 33. Foliar Cover of Seeded Species and Cheatgrass, 2007. There is higher cover by seeded species in plots with the higher seed rate and more diverse seed mix. Cover by cheatgrass is highest in the shrub seed only plot (1a).

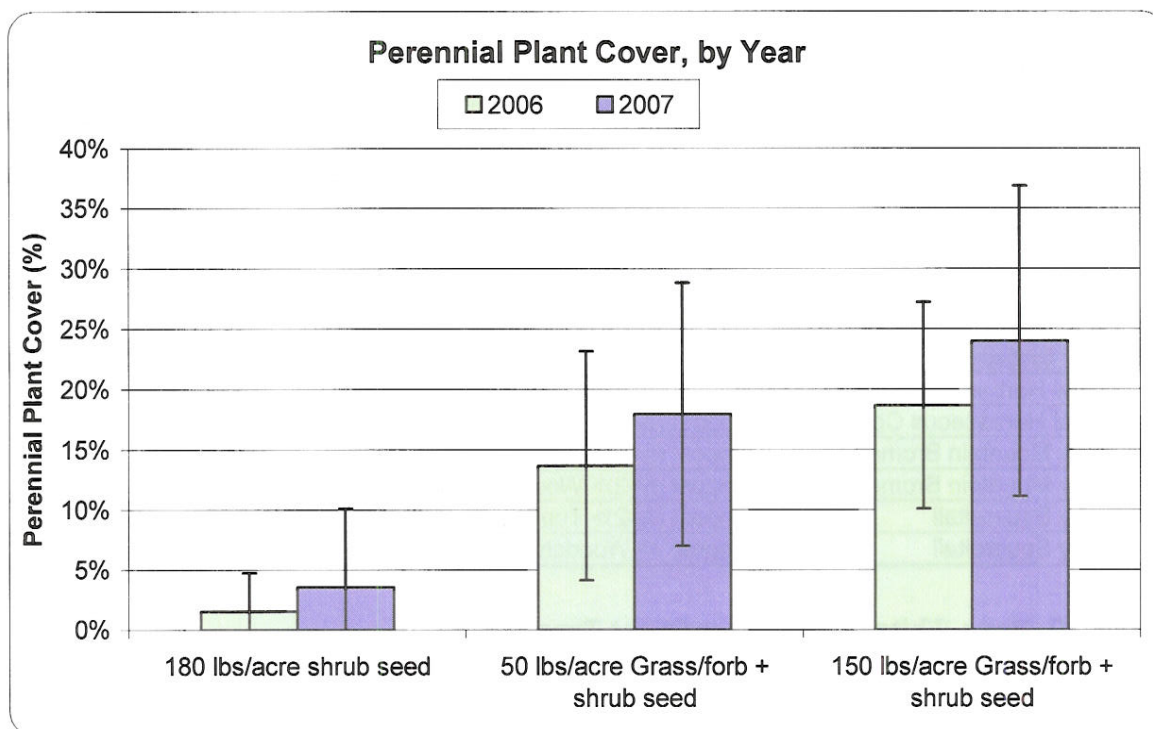


Figure 34. Perennial Plant Cover, by Year. Perennial plant cover is highest in plots with the higher seed rate and more diverse seed mix. Error bars denote one standard deviation above and below the mean.

Table 7. T-test results of December 2006 penetrometer depths and soil moisture comparisons.

Variable	Outcome	T statistic, sample n_1 and n_2 and P value	Conclusion
Soil moisture (%)	Surface treatment with planting > Irrigated	$t=.281$ ($n_1 = 30, n_2=10$) $p=0.78$	There is <u>no difference</u> between no-till and Caltrans irrigated soil moistures
Soil moisture (%)	Irrigated > Soil Loosened	$t=-4.68$ ($n_1 = 60, n_2=10$) $p<0.001$	Caltrans irrigated plot soil moisture is greater than the soil moisture at the test plots with soil loosening
Penetrometer DTR	Irrigated > Soil loosened	$t=-5.75$ ($n_1 = 60, n_2=10$) $p<0.0001$	Caltrans irrigated plot penetrometer DTR is greater than the soil loosening test plot DTRs
Penetrometer DTR	Soil loosened > Surface treatment with	$t=23.5$ ($n_1 = 60, n_2=30$) $p<0.0001$	Soil loosened test plot penetrometer DTRs are greater than the DTRs at the no-till test plot.

Table 8. 2006 Tukey test results of cover differences by amendment type. Only values significant at the 80% confidence level or with a p-value < 0.2 were reported

Variable tested	Factor tested	q-value	Probability
Perennial Herbaceous Cover	Compost (n=2) > Tub grindings (n=6)	4.77	p< 0.05
Perennial Herbaceous Cover	Compost (n=2) > Woodchips (n=2)	5.421	p< 0.025
Cover by Mountain Brome	Compost (n=2) > Tub grindings (n=6)	3.467	p< 0.1
Cover by Mountain Brome	Compost (n=2) > Woodchips (n=2)	5.067	p< 0.025
Cover by Squirreltail	Compost (n=2) > Tub grindings (n=6)	6.337	p< 0.01
Cover by Squirreltail	Compost (n=2) > Woodchips (n=2)	4.615	p< 0.05

Table 9. 2007 Tukey test results of cover differences by amendment type.

Variable tested	Factor tested	q-value	Probability
Perennial Herbaceous Cover	Compost (n=2)> Tub grindings (n=6)	5.214	p< 0.025
Perennial Herbaceous Cover	Compost (n=2)> Woodchips (n=2)	4.483	p< 0.05
Cover by Mountain Brome	Compost (n=2)> Tub grindings (n=6)	5.072	p< 0.025
Cover by Mountain Brome	Compost (n=2)> Woodchips (n=2)	3.109	p< 0.15
Cover by Squirreltail	Compost (n=2)> Tub grindings (n=6)	4.237	p< 0.1
Cover by Squirreltail	Compost v> Woodchips (n=2)	4.460	p< 0.05

Table 10. Mann-Whitney Test Amendment Type and Biosol

Variable tested	Factor tested	U-value and p-value
Perennial Plant Cover, 2006	Compost (n=2)> Tub grindings (n=6)	U=12, p=0.071
Cover by Mountain Brome, 2006	Compost (n=2)> Tub grindings (n=6)	U=12, p=0.071
Cover by Squirreltail, 2006	Compost (n=2)> Tub grindings (n=6)	U=12, p=0.071
Perennial Herbaceous, 2007 Cover	Compost (n=2)> Tub grindings (n=6)	U=12, p=0.071
Cover by Squirreltail, 2007	Compost (n=2)> Tub grindings (n=6)	U=12, p=0.071
Cover by Mountain Brome, 2007	Compost (n=2)> Tub grindings (n=6)	U=11, p=0.143
Total Plant Cover, 2007	2K Biosol (n=6) > 4K Biosol (n=6)	U = 27, p = 0.18
Cover by Perennial Species, 2007	2K Biosol (n=6) > 4K Biosol (n=6)	U = 27, p = 0.18
Cover by Seeded Species, 2007	2K Biosol (n=6) > 4K Biosol (n=6)	U = 27, p = 0.18
Cover by Perennial Species, 2006	Grass Forb Seed (n=8) > Shrub only seed (n=2)	U = 20, p = 0.03
Cover by Perennial Species, 2007	Grass Forb Seed (n=8) > Shrub only seed (n=2)	U = 20, p = 0.03
Cover by Seeded Species, 2006	Grass Forb Seed (n=8) > Shrub only seed (n=2)	U = 20, p = 0.03
Cover by Seeded Species, 2007	Grass Forb Seed (n=8) > Shrub only seed (n=2)	U = 20, p = 0.03

Soil Nutrients

In 2006, all plots that had both an amendment (compost, tub grindings, or composted woodchips) and Biosol had total Kjeldahl nitrogen (TKN) values that were similar to or higher than the TKN at the native site (Figure 35). The native site TKN was 1,176 ppm, and the range of TKN values at the plots with amendments and Biosol was 1,156 to 1,607 ppm.

Plots with compost had the highest TKN in 2006 (1,607 ppm) compared to plots with other amendments, that ranged from 1,156 to 1,244 ppm (Figure 35).

TKN values decreased at the full treatment plots between 2006 and 2007 (Figure 35). In 2007, the TKN ranged from 923 ppm to 1,156 ppm, compared to 1,154 to 1,607 in 2006. TKN values often decrease when plant production increases, as plants take up nitrogen.

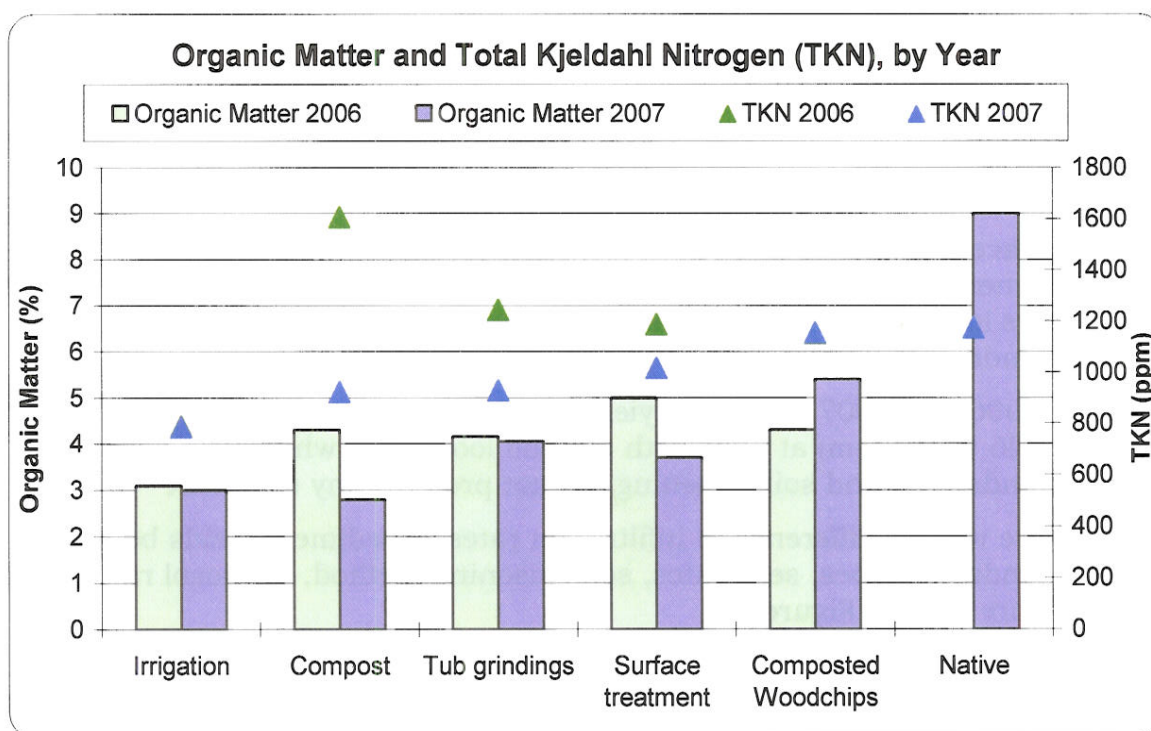


Figure 35. Organic Matter and Total Kjeldahl Nitrogen (TKN) by Year. Data is sorted by 2007 TKN values. TKN and organic matter decreased at most sites between 2006 and 2007. The irrigated site had the lowest TKN and one of the lowest organic matter levels.

The TKN at the Caltrans irrigated plot was lower than any other treatment plot in 2006 (790 ppm) and 2007 (785 ppm, Figure 35). In 2006, the Caltrans irrigated plot had the lowest percentage of organic matter, 3.1%, while in 2007, it was one of the lowest values, 3% (Figure 35). The consistently low TKN and organic matter within the irrigated plot indicates that soil nutrients may be a limiting factor to plant growth. The plant growth decreased at this site from

2006 to 2007, while plant cover remained the same at the surface treatment plot without irrigation. It is possible that some of the soil nitrogen or organic matter may have leached out of the soil as a result of the irrigation because the surface treatment plot without irrigation had higher TKN (1,018 to 1,188 ppm) and organic matter levels (3.7 to 5%, Figure 35).

Solar Radiation

Solar radiation is a measurement of the amount of unimpeded sunlight that a site receives. Sites with a high canopy cover are generally associated with a low solar radiation measurement. The Truckee Bypass test plots face northeast, so they do not receive a great amount of sunlight in winter months, but there is little canopy cover to interfere with summer sunlight. The average solar exposure in August of any given year at the Truckee Bypass test plot area is 89 percent while the average solar radiation at the irrigated plot is 98 percent. Both of these values are high, which indicates that sunlight would not be a limiting factor at these sites during the summer months.

CONCLUSIONS

Infiltration

- Surface treatments without soil loosening and amendments had sediment yields that were higher and infiltration rates that were 1.4 times lower than the full treatment plots with soil loosening and amendments (Figure 18 and Figure 19).
- In 2006 and 2007, sediment yields ranged from 5 to 286 lbs/acre/in (2.2 to 126 kg/ha/cm) at plots with out soil loosening, while plots with amendments and soil loosening did not produce any sediment
- There was no difference in infiltration rates or sediment yields between amendment types, seed rates, soil loosening method, or Biosol rates (Figure 18 and Figure 19).
- Plots with higher sediment yields and lower infiltration rates (full treatment plots) had wetting depths that were at least 1.6 times deeper than those at plots with high sediment yields and low infiltration rates (surface treatment plots, Figure 18 and Figure 19).
- In 2007, the wetting depth at the ripped plot was 1.5 times shallower than the wetting depth at the tilled plots with the same soil amendment (Figure 19).

Soil Density

- In 2006, soil loosened (tilled or ripped) plots had DTRs that were approximately 2.5 times deeper than at the surface treatment plots without irrigation.
- In 2007, soil loosened plots had DTRs that were similar to the DTRs at the irrigated plots and approximately 3 times deeper than at the surface treatment plots (Figure 21).
- There was no difference in soil density between ripped plots and tilled plots (Figure 21).

Soil Strength

- All plots had similar shear strength values that were comparable to those at the native plot (Figure 22).

Mulch Cover

- In 2006 and 2007, all of the surface treatment plots, which had mulch cover that ranged from 50 to 72%, produced sediment (Figure 18, Figure 19, Figure 25, and Figure 26).
- In 2006 and 2007, plots with mulch cover greater than 89% (this included all full treatment plots) did not produce sediment (Figure 18, Figure 19, Figure 25, and Figure 26).

Plant Cover

- In 2006 and 2007, full treatment plots with soil loosening and amendments had plant cover that was 3.4 times higher than plots with surface treatment. The full treatment plots also had 8.8 times more cover by seeded perennial species.
- In 2006 and 2007, compost plots had at least 1.7 times more total plant cover and 2.2 to 2.7 times more cover by seeded perennial grasses (squirreltail and mountain brome) when compared to plots with tub grindings (Figure 27, Figure 28, Figure 29, Figure 30, Table 8, and Table 9).
- There was no significant difference in total plant cover for ripped plots versus tilled plots in 2006 or 2007.
- In 2007 (though not 2006), total plant cover, cover by perennial species, and cover by seeded species was approximately 2 times higher in plots with 2,000 lbs/acre (2,250 kg/ha) of Biosol when compared to plots with 4,000 lbs/acre (4,483 kg/ha, Table 10 and Figure 31).

- In both 2006 and 2007, the plot with the shrub only seed mix (1a) had 5 to 10 times less cover by perennial species and 16 to 23 times less cover by seeded species when compared to plots that received the mix primarily composed of grasses (Figure 32, Figure 33, and Figure 34 and Table 10).
- In 2007 plots with the higher seed rate had 1.1 times more cover by perennial species, and 1.2 times more cover by seeded species on average compared to plots with the lower seed rate (50 lbs/acre, Figure 34)
- Most of the plant cover at the irrigated site was dependent on irrigation for growth, while the amended test plots maintained perennial plant growth without irrigation.
- Between 2006 and 2007, cover by mountain brome decreased by 1 to 4% at each plot, while cover by squirreltail increased by 1 to 14% (Figure 27 and Figure 28). These changes were related to the decrease in precipitation between 2006 and 2007.
- Despite the lower annual precipitation, cover by desirable perennial species at the soil loosened test plots was on average 1.2 times higher in 2007 than in 2006 (Figure 27, Figure 28, Figure 32, and Figure 33).

Soil Nutrients

- In 2006, all plots that had both an amendment (compost, tub grindings, or composted woodchips) and Biosol had total Kjeldahl nitrogen (TKN) values that were similar to or higher than the TKN at the native site (Figure 35).
- Plots with compost had the highest TKN in 2006 (1,607 ppm) compared to plots with other amendments, that ranged from 1,156 to 1,244 ppm (Figure 35).
- TKN values decreased at the full treatment plots between 2006 and 2007, most likely due to the uptake of nitrogen by plants (Figure 35).
- TKN at the Caltrans irrigated plot was lower than any other treatment plot in 2006 (790 ppm) and 2007 (785 pm, Figure 35). It is possible that some of the soil nitrogen or organic matter may have leached out of the soil as a result of the irrigation since surface treatment plot without irrigation had higher TKN (1,018 to 1,188 ppm) and organic matter levels (3.7 to 5%, Figure 35).

RECOMMENDATIONS

These recommendations are for sites with rocky soils on volcanic parent material, with slope angles between 20 and 25 degrees, solar exposures of 89 – 98% during the summer months, at 5,765 feet (1,758 meters) AMSL:

Tilling: 12 inches

Amendment: 3 inches compost with 25% fines and 75% coarse overs at a nitrogen equivalent of approximately 1,908 lbs/acre (2,139 kg/ha)

Biosol: 2,000 lbs/acre (2,250 kg/ha)

Seed: 150 lbs/acre seed with the following composition:

- squirreltail: 40%
- mountain brome: 25%
- Western needlegrass 25%
- native forbs and shrubs: 10%

Mulch: pine needles, 2 inches and 99% cover

Full treatment versus Surface Treatment

Full treatment is recommended over surface treatment because full treatment plots exhibited:

- no sediment yield, compared to sediment yields that ranged from 5 to 286 lbs/acre/in (2.2 to 126 kg/ha/cm) at the surface treatment plots
- infiltration rates that were 1.4 times higher than the infiltration rates at the surface treatment plots
- soil density that was 2.5 times less than at the surface treatment plots without irrigation (soil moisture variations did not allow for comparison to the surface treatment plot with irrigation)
- on average 3.4 times higher plant cover than at surface treatment plots
- on average 8.8 times higher seeded perennial plant cover when compared to the surface treatment plots
- 1.2 to 1.8 times higher cover by mulch, greater than 89%, compared to mulch cover at the surface treatment plots, that ranged from 50 to 72%

Soil Loosening Method (Tilling versus Ripping)

Either tilling or ripping is recommended for the following reason:

- There was no difference in infiltration rates, soil density or plant cover between ripped plots and tilled plots

Soil Loosening versus No Soil Loosening.

Tilling or ripping is recommended to a depth of 12 inches for the following reasons. Plots with soil loosening exhibited:

- no sediment yield, compared to sediment yields that ranged from 5 to 286 lbs/acre/in (2.2 to 126 kg/ha/cm) at the surface treatment plots without soil loosening
- infiltration rates that were 1.4 times higher than the infiltration rates at the surface treatment plots without soil loosening
- soil density that was 2.5 times less than at the untilled surface treatment plots without irrigation (soil moisture variations did not allow for comparison to the unloosened surface treatment plot with irrigation)
- on average 3.4 times higher plant cover than at surface treatment plots without soil loosening
- on average 8.8 times higher seeded perennial plant cover when compared to the surface treatment plots without soil loosening
- 1.2 to 1.8 times higher cover by mulch, greater than 89%, compared to mulch cover at the surface treatment plots, that ranged from 50 to 72%

Amendment Type and Rate (Compost versus Tub grindings versus Composted Woodchips)

Compost, composed of 25% fine material and 75% coarse overs, applied to 3 inch depth at a nitrogen equivalent of approximately 1,908 lbs/acre (2,139 kg/ha), is recommended over tub grindings or composted woodchips for the following reasons. Plots with compost applied to a depth of 3 inches exhibited:

- at least 1.7 times more total plant cover and 2.2 to 2.7 times more cover by seeded perennial grasses (squirreltail and mountain brome) when compared to plots with tub grindings
- the highest soil TKN in 2006 (1,607 ppm compared to a range of 1,156 to 1,244 ppm for the plots with tub grindings or composted woodchips)
- TKN that was similar to that at the native site
- The same infiltration rates to plots amended with tub grindings or composted woodchips
- no sediment yield (plots with tub grinding or composted woodchips did not produce any sediment)
- similar soil densities to plots with tub grindings or composted woodchips

Biosol Rate

Biosol is recommended at a rate of 2,000 lbs/acre (2,250 kg/ha) rather than 4,000 lbs/acre (4,483 kg/ha) for the following reasons. Plots with 2,000 lbs/acre of Biosol exhibited:

- total plant cover, cover by perennial species, and cover by seeded species in 2007 that was approximately 2 times higher than in plots with 4,000 lbs/acre (4,483 kg/ha) of Biosol

Seed Rate

Native seed is recommended at a rate 150 lbs/acre. Suggested species composition is:

squirreltail: 40%
 mountain brome: 25%
 Western needlegrass: 25%
 native forbs and shrubs: 10%

For the following reasons:

- In 2007, a drought year, cover by mountain brome decreased by 1 to 4% on treated plots, while cover by squirreltail increased by 1 to 14% on treated plots. Therefore, the proportion of squirreltail increased and mountain brome decreased.
- In both 2006 and 2007, the plot with the shrub only seed mix (1a) had 5 to 10 times less cover by perennial species and 16 to 23 times less cover by seeded species when compared to plots that received the mix primarily composed of grasses.

Mulch Cover and Depth

Mulch composed of native pine needles should be applied at a depth of 2 inches and a ground cover of at least 99% for the following reasons. Plots with this application exhibited:

- mulch cover greater than 89% in 2007 (Figure 25 and Figure 26).
- no sediment production in 2006 or 2007 (Figure 18 and Figure 19).

Irrigation

Irrigation is not recommended for the following reasons:

- Plant cover at the irrigated site decreased from 48 to 12% after the irrigation was removed because plants at the irrigated site were dependent on artificial irrigation for growth (Figure 27 and Figure 28).
- Annual species, such as Spanish clover, were dominant (Figure 27 and Figure 28).

- The irrigated site did not perform well in rainfall simulations and produced a two-year average infiltration rate of 3.4 inches/hour (86 mm/hr) and a two-year average sediment yield of 110 lbs/acre/in (49 kg/ha/cm).
- The TKN at the Caltrans irrigated plot was lower than any other treatment plot in 2006 (790 ppm) and 2007 (785 pm), both of which are below that at the native site.

Appendix A

Species list for Truckee Bypass test plots, 2006. Ocular estimates are presented under each plot number/letter in columns. T = trace amount of cover

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	Phenology	Ocular Estimate (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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Forb	Asteraceae	Achillea millefolium	yarrow	Perennial	Native		Veg.	T	T		T																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	Phenology	Ocular Estimate (%)												
								Plot 1A	Plot 2A	Plot 3A	Plot 1B	Plot 2B	Plot 3B	Plot 4B	Plot 5B	Plot 6B	Plot NT	Plot X	Plot IRR	
Forb	Scrophulariaceae	Pedicularis semibarbata	lousewort	Perennial	Native		Veg.													
Forb	Scrophulariaceae	Penstemon laevis	gay penstemon	Perennial	Native		Flower													
Forb	Hydrophyllaceae	Phacelia hastata	silverleaf phacelia	Perennial	Native		Veg.													
Forb	Polemoniaceae	Phlox gracilis	slender phlox	Annual	Native		Dry	T												
Forb	Polygonaceae	Polygonum arenastrum	common knotweed	Annual	Native		Flower	20		5 - 10	10 -	T		T	< 5	< 5	35	15 - 20	5	
Forb	Polygonaceae	Polygonum douglasii	Douglas knotweed	Annual	Native		Flower		< 5								T			
Forb	Ericaceae	Pyrola picta	wintergreen	Perennial	Native		Veg.													
Forb	Brassicaceae	Sisymbrium albidissimum	tumble mustard	Annual	Alien		Seed										T			
Forb	Apiaceae	Sphenosciadium	ranger's buttons	Perennial	Native		Flower													
Forb	Asteraceae	Taraxacum officinale	dandelion	Annual	Alien	Invasive	Veg.													
Forb	Asteraceae	Tragopogon dubius	false salsify	Annual	Alien		Seed											T		
Forb	Fabaceae	Trifolium repens	white clover	Perennial	Alien		Veg.													
Forb	Scrophulariaceae	Verbascum thapsis	mullen	Annual	Native	Invasive	Flower													
Forb	Portulacaceae	Calyptridium umbellatum	pussy paws	Perennial	Native		past seed												T	
		Nelson's																		
Graminoid	Poaceae	Achnatherum nelsonii	Western	Perennial	Native		Seed													
Graminoid	Poaceae	Achnatherum		Perennial	Native		Seed													
Graminoid	Poaceae	Agropyron	pubescent	Perennial	Alien															
Graminoid	Poaceae	Agropyron intermedium	intermediate	Perennial	Alien															
Graminoid	Poaceae	Bromus carinatus	mountain brome	Perennial	Native				25 -	30		25	25	15	30	40				5
Graminoid	Poaceae	Bromus tectorum	cheatgrass	Annual	Alien	Invasive	Seed	< 5	5 - 10			T	< 5	T	T	T				
Graminoid	Poaceae	Dactylis glomerata	orchard grass	Perennial	Alien	Invasive	Veg.													
Graminoid	Poaceae	Deschampsia elongata	elongated hairgrass	Perennial	Native		Seed													
Graminoid	Poaceae	Elymus elymoides	squirrel's tail grass	Perennial	Native		Flower	T	10	5 - 15		10 -						T		< 5
Graminoid	Poaceae	Elymus glaucus	blue wildrye	Perennial	Native		Seed												5	
Graminoid	Poaceae	Festuca	Fescue	Perennial	Native		Veg.													T
Graminoid	Poaceae	Hordeum vulgare	barley	Annual	Alien		Flower													
Graminoid	Poaceae	Poa bulbosa	bulbous bluegrass	Perennial	Alien		Seed													
Graminoid	Poaceae	Poa secunda	Secund's bluegrass	Perennial	Native		Seed											T		
Shrub	Ericaceae	Arctostaphylos	pinemat manzanita	Perennial	Native		Veg.													
Shrub	Asteraceae	Artemisia tridentata	sagebrush	Perennial	Native		seedling			T						T		< 5		
Shrub	Ranunculaceae	Ceanothus cordulanthus	buckthorn	Perennial	Native		Veg.													
Shrub	Rosaceae	Purshia tridentata	bitterbrush	Perennial	Native		seedling	T		T						T				
Shrub	Rosaceae	Rubus parviflorus	thimbleberry	Perennial	Native		Veg.													
Shrub	Caprifoliaceae	Symphoricarpos mollis	trailing snowberry	Perennial	Native		Veg.													

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	Phenology	Ocular Estimate (%)											
								Plot 1A	Plot 2A	Plot 3A	Plot 1B	Plot 2B	Plot 3B	Plot 4B	Plot 5B	Plot 6B	Plot NT	Plot X	Plot IRR
Tree	Pinaceae	Abies concolor	white fir	Perennial	Native		sapling		T										
Tree	Pinaceae	Pinus jefferyi	Jeffrey pine	Perennial	Native		seedling	T		T	T			T			T	T	T

Species list for Truckee Bypass test plots, 2007. Ocular estimates are presented under each plot number/letter in columns. T = trace amount of

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious	In seed mix?	Plot 1A	Plot 2A	Plot 3A	Plot 4A	Plot 5A	Plot 6A	Plot 1B	Plot 2B	Plot 3B	Plot 4B	Plot 5B	Plot 6B	Plot NT	Plot X	Plot IRR	Plot N
Forb	Asteraceae	Achillea millefolium	yarrow	Perennial	Native			T	T				T	T	T	<5				<5	<5	5	
Forb	Asteraceae	Agoseris retosa	false dandelion	Perennial	Native																		
Forb	Asteraceae	Antennaria rosea	pussy toes	Perennial	Native																		
Forb	Brassicaceae	Arabis holboellii	Holboell's rockcress	Perennial	Native																		T
Forb	Asteraceae	Aster ascendens	long-leaved aster	Perennial	Native			<5	25 - 30	30	30 - 40	30 - 40	50 - 60		25	25	15	30	40			5	
Forb	Portulacaceae	Calyptidium umbellatum	pussy paws	Perennial	Native																		
Forb	Brassicaceae	Capsella bursa-pastoris	shepherd's purse	Annual	Alien	Invasive																	
Forb	Asteraceae	Chaenactis douglasii	Douglas pincushion	Perennial	Native																		
Forb	Chenopodiaceae	Chenopodium album	goosefoot	Annual	Alien			T				T	<5			T			T				
Forb	Asteraceae	Cirsium andersonii	Anderson's thistle	Perennial	Native			T	T	<5				T	<5	<5				10 - 15	5		
Forb	Scrophulariaceae	Collinsia parviflora	blue-eyed mary	Annual	Native							<5	5				T	<5					
Forb	Polemoniaceae	Collomia linearis	narrow-leaved collomia	Annual	Native			10 - 20	15	5 - 10	15 - 20	5 - 10	5 - 10	5 - 10	<5	<5			5 - 10	10	10 - 15		
Forb	Polemoniaceae	Collomia tinctoria	staining collomia	Annual	Native																		
Forb	Boraginaceae	Cryptantha ambigua	Wilke's cryptantha	Annual	Native																		T
Forb	Brassicaceae	Descurainia sophia	herb Sophia	Annual	Alien	Invasive																5	
Forb	Polygonaceae	Eriogonum nudum	nude buckwheat	Perennial	Native																		
Forb	Polygonaceae	Eriogonum umbellatum	sulfur flower	Perennial	Native																	T	
Forb	Geraniaceae	Erodium cicutarium	red stem storkbill	Annual	Alien	Invasive		20 - 30	<5	5 - 10	5 - 10	<5	5	10	<5		<5	<5	<5	20		25	
Forb	Brassicaceae	Erysimum capitatum	wall flower	Perennial	Native																		T
Forb	Onagraceae	Gayophytum diffusum	prairie smoke	Perennial	Native			T		T	<5	T	T	T	<5	T	<5	<5	<5	T		<5	T
Forb	Asteraceae	Hieracium albiflorum	Hawkweed	Perennial	Native																		
Forb	Asteraceae	Lactuca serriola	devil's lettuce	Annual	Alien	Invasive																	
Forb	Fabaceae	Lathyrus latifolius	sweet pea	Perennial	Alien			<5			T		T			T		T	T				
Forb	Brassicaceae	Lepidium campestre	English pepperweed	Annual	Alien									T			T		T			60	
Forb	Asteraceae	Leucanthemum vulgare	ox-eye daisy	Perennial	Alien	Invasive							T	T					T	T	T	5	
Forb	Polemoniaceae	Linanthus harknessii	Harkness's linanthus	Annual	Native						T	5	<5			<5	T			T	<5	50	
Forb	Fabaceae	Lotus purshianus	Spanish lotus	Perennial	Native			T	T						T		T						
Forb	Fabaceae	Lupinus argenteus	silver lupine	Perennial	Native								T						T				
Forb	Fabaceae	Lupinus lepidus (culbertsonii)	Culbertson's lupine	Perennial	Native																	T	
Forb	Asteraceae	Madia glomerata	mountain tarweed	Annual	Native																		
Forb	Fabaceae	Mellilotus albus	white sweet clover	Annual	Alien									T						T			
Forb	Fabaceae	Mellilotus officinalis	yellow sweet clover	Annual	Alien																		
Forb	Lamiaceae	Monardella odoratissima	mountain monardella	Perennial	Native																		
Forb	Polemoniaceae	Navaretia	navaretia	Annual	Native																		

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious	In seed mix?	Plot 1A	Plot 2A	Plot 3A	Plot 4A	Plot 5A	Plot 6A	Plot 1B	Plot 2B	Plot 3B	Plot 4B	Plot 5B	Plot 6B	Plot NT	Plot X	Plot IRR	Plot N
Forb	Onagraceae	Oenothera sp.	evening primrose	Perennial	Native																		
Forb	Scrophulariaceae	Pedicularis semibarbata	lousewort	Perennial	Native			T															
Forb	Scrophulariaceae	Penstemon laevis	gay penstemon	Perennial	Native			T		T					T	T					T		
Forb	Hydrophyllaceae	Phacelia hastata	silverleaf phacelia	Perennial	Native								T										
Forb	Polemoniaceae	Phlox gracilis	slender phlox	Annual	Native																T		
Forb	Polygonaceae	Polygonum arenastrum	common knotweed	Annual	Native														T				
Forb	Polygonaceae	Polygonum douglasii	Douglas knotweed	Annual	Native																		
Forb	Ericaceae	Pyrola picta	wintergreen	Perennial	Native																		
Forb	Brassicaceae	Sisymbrium altissimum	tumble mustard	Annual	Alien																		
Forb	Apiaceae	Sphenosciadium capitellatum	ranger's buttons	Perennial	Native																		
Forb	Asteraceae	Taraxacum officinale	dandelion	Annual	Alien	Invasive																	
Forb	Asteraceae	Tragopogon dubius	false salsify	Annual	Alien			T						T	T						T		
Forb	Fabaceae	Trifolium repens	white clover	Perennial	Alien																		
Forb	Scrophulariaceae	Verbasicum thapsis	mullein	Annual	Native	Invasive																	
Forb	Asteraceae	Wyethia mollis	mule's ear	Perennial	Native			T						T							T		
Graminoid	Poaceae	Achnatherum nelsonii	Nelson's needlegrass	Perennial	Native																		
Graminoid	Poaceae	Achnatherum occidentale	Western needlegrass	Perennial	Native		X																
Graminoid	Poaceae	Agropyron dasystachyum	pubescent wheatgrass	Perennial	Alien																		
Graminoid	Poaceae	Agropyron intermedium	wheatgrass	Perennial	Alien																		
Graminoid	Poaceae	Bromus carinatus	mountain brome	Perennial	Native		X	< 5	5 - 10		T	T			T	< 5	T	T	T				
Graminoid	Poaceae	Bromus tectorum	cheatgrass	Annual	Alien	Invasive															T		
Graminoid	Cyperaceae	Carex rossii	Ross's sedge	Perennial	Native																		T
Graminoid	Poaceae	Dactylis glomerata	orchard grass	Perennial	Alien	Invasive																	
Graminoid	Poaceae	Deschampsia elongata	elongated hairgrass	Perennial	Native			T	10	5 - 15	10	5	10		10 - 15	10	5 - 10	15	10	T			< 5
Graminoid	Poaceae	Elymus elymoides	squirrel's tail grass	Perennial	Native		X						T										5
Graminoid	Poaceae	Elymus glaucus	blue wildrye	Perennial	Native		X	< 5					T	< 5	T	T		T			< 5		
Graminoid	Poaceae	Festuca	Fescue	Perennial	Native																		
Graminoid	Poaceae	Hordeum vulgare	barley	Annual	Alien									T									
Graminoid	Poaceae	Poa bulbosa	bulbous bluegrass	Perennial	Alien				< 5			< 5		10 - 15					T				
Graminoid	Poaceae	Poa pratensis	Kentucky bluegrass	Perennial	Native			T		T		T				T	T						
Graminoid	Poaceae	Poa secunda	Secund's bluegrass	Perennial	Native																		
Graminoid	Poaceae	Poa wheeleri	Wheeler's bluegrass	Perennial	Native																		10
Shrub	Ericaceae	Arctostaphylos nevadensis	pinemat manzanita	Perennial	Native					T		T						T			< 5		
Shrub	Asteraceae	Artemisia tridentata	sagebrush	Perennial	Native																		
Shrub	Rhamnaceae	Ceanothus cordulanthus	buckthorne	Perennial	Native			T		T			T	T	T	T			T		T		
Shrub	Rosaceae	Purshia tridentata	bitterbrush	Perennial	Native																		T

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious	In seed mix?	Plot 1A	Plot 2A	Plot 3A	Plot 4A	Plot 5A	Plot 6A	Plot 1B	Plot 2B	Plot 3B	Plot 4B	Plot 5B	Plot 6B	Plot NT	Plot X	Plot IRR	Plot N
Shrub	Rosaceae	Rubus parviflorus	thimbleberry	Perennial	Native															T			
Shrub	Caprifoliaceae	Symphoricarpos mollis	trailing snowberry	Perennial	Native																		
Tree	Pinaceae	Abies concolor	white fir	Perennial	Native				T														
Tree	Pinaceae	Pinus jefferyi	Jeffrey pine	Perennial	Native			20		5 - 10			T		T		T	< 5	< 5	35	15 - 20	5	30 OS